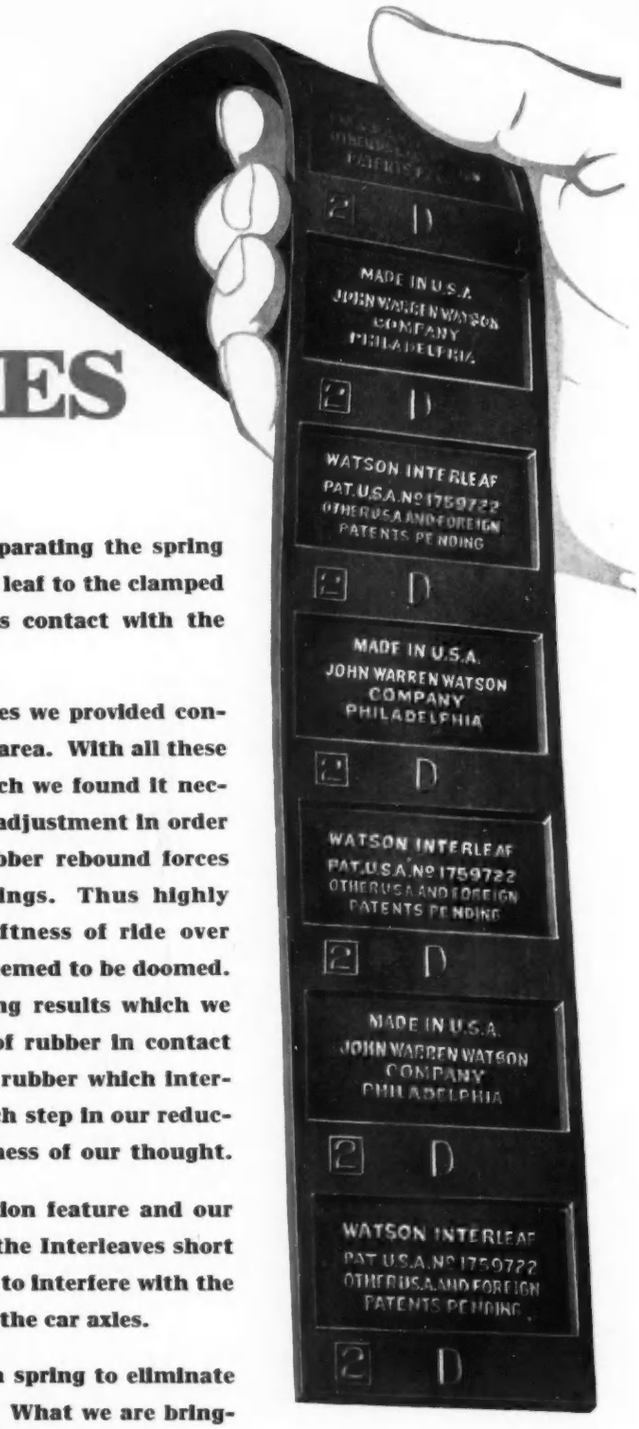
S·A·E JOURNAL

APRIL 1931

WATSON . . . RUBBER INTERLEAVES



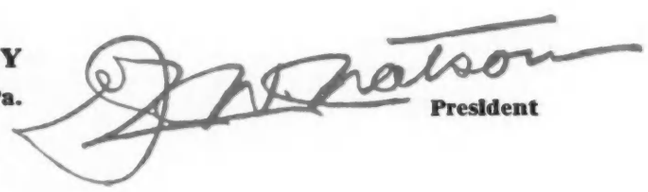
While perfectly supporting and separating the spring leaves for the entire distance from the tip of the leaf to the clamped section, Watson Rubber Interleaves nevertheless contact with the leaves for only about 20% of the leaf area.

In our early experiments with Rubber Interleaves we provided contact with the leaves over nearly 100% of the leaf area. With all these hundreds of square inches of rubber under stretch we found it necessary to carry the shock absorbers at very high adjustment in order to adequately hold the combined steel and rubber rebound forces following heavy compressions of the car springs. Thus highly adjusted, the shock absorbers spoiled the softness of ride over smoother roads. Rubber Interleaves therefore seemed to be doomed. Then it occurred to us that the complete riding results which we wanted could be had by reducing the amount of rubber in contact with the spring leaves and thus the amount of rubber which interleaf movement would cause to be stretched. Each step in our reduction of the rubber in contact proved the soundness of our thought.

Our patents are pending on this rubber-reduction feature and our patents have already been granted on stopping the Interleaves short of the clamped section so as not to permit them to interfere with the firm and secure clamping of the spring leaves to the car axles.

The art of using rubber between the leaves of a spring to eliminate friction is now old by more than half a century. What we are bringing to the Industry is a form of specific Interleaf design and construction which can be easily and accurately installed, which properly supports the leaves, and which works to produce a new wonder in riding comfort. In our opinion these Watson Interleaves mark the greatest advance yet made in the interest of easy riding.

JOHN WARREN WATSON COMPANY
Philadelphia, Pa.



President

S·A·E· JOURNAL

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 *W. 39th St., New York*
Cable Address: AUTOENG *Telephone:* LONGACRE 5-7170

VINCENT BENDIX, *President* — JOHN A. C. WARNER, *Secretary* — C. W. SPICER, *Treasurer*

Vol. XXVIII — April, 1931 — No. 4

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The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

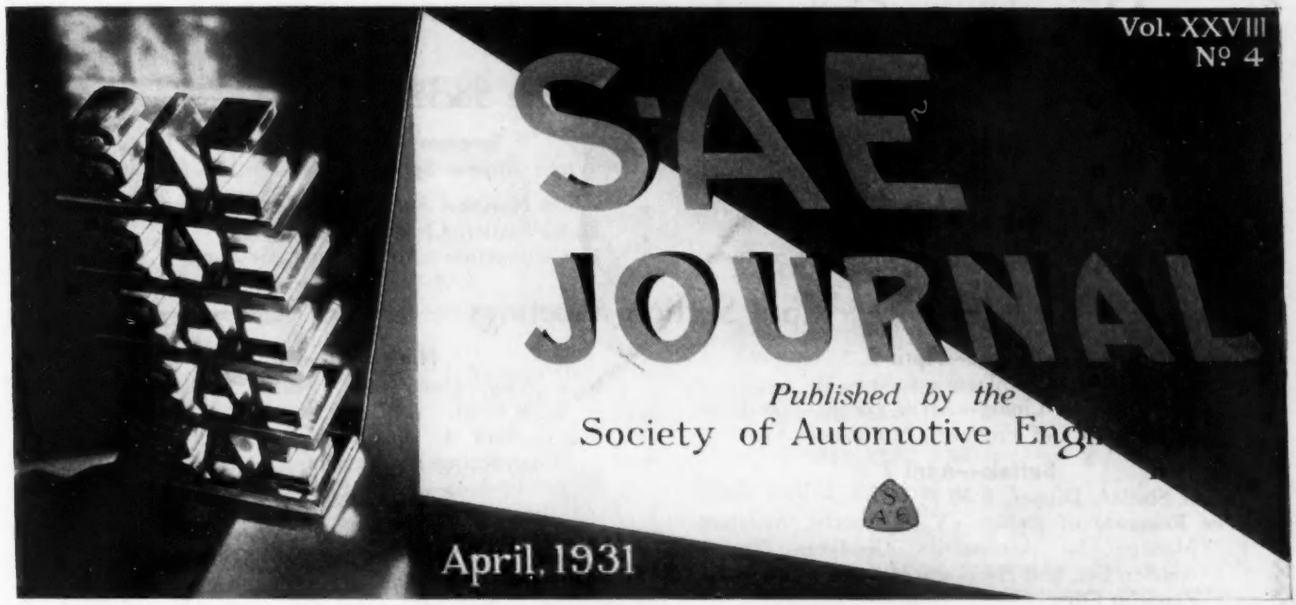
ON THE AIRWAYS TO-DAY

– as on the highways for the last 30 years –

Guaranteed Forgings

WYMAN-GORDON

WORCESTER, MASS. AND HARVEY, ILL.



April Aeronautic Meeting

Fifteen Papers To Be Presented at Six Technical Sessions — Spring Production Meeting and Summer Meeting Plans

AN UNUSUALLY timely series of papers on subjects of vital interest to the industry is to be presented at the 19th National Aeronautic Meeting of the Society, which is to be held on April 15 and 16 during the week of the International Aircraft Exposition in Detroit. There are to be six technical sessions, with 15 papers.

As will be noted in the program of the meeting on p. 405 of this issue, six papers, aside from those on fuels, are to be given for the aircraft-engine designer. In view of the great interest in the development of light, low-powered engines, the paper on this type of engine, by R. N. Dubois, of the Continental Aircraft Co., will be very timely. Similarly, it is hoped that the paper on Spark-Plugs, by G. M. Paulson, of the B. G. Corp., will contribute to the clearing up of the very controversial subject of this item in aircraft engines.

The other engine papers, Superchargers and Supercharging, by Oscar Schey, of the National Advisory Committee for Aeronautics; Bearing-Load Analysis and Permissible Loads, by F. L. Prescott and R. B. Poole, of the Army Air Corps, at Wright Field; High-Temperature Liquid-Cooling, by Arthur Nutt, of the Wright Aeronautical Corp.; and the one on Airplane Fuel-Line Temperatures, by Dr. O. C. Bridgeman, of the Bureau of Standards, present very valuable data as a result of much research carried on in the last six or eight months, and should be of considerable importance to the industry.

Fuel Antiknock-Rating Symposium

Because of the difficulties and misunderstandings that have arisen in the past with the knock rating of aviation gasoline, the Aircraft-Engine Committee has distributed to various laboratories for test work samples of gasolines of five different specifications. The knock-rating experiments on these gasolines and the results obtained will be coordinated into a paper to be given by H. K. Cummings, of the Bureau of Standards. The results of rating of these gasolines by flight testing will be given at the same session in a second paper by a representative of the Pratt & Whitney Aircraft Co., to be followed by a report on further laboratory tests and data on knock rating by Dr. Graham Edgar, of the Ethyl Gasoline Corp., the data being the result of cooperative work by several of the well-known testing laboratories.

Aerodynamics and aircraft design are to be dealt with in four papers. A treatise on Commercial Flight-Testing by E. W. Rounds, of the Bureau of Aeronautics, and the latest developments of the Autogiro, to be described by W. Laurence LePage, of the Kellett Aircraft Corp., are of particular interest. An excellent paper on Load Factors in Airplane Design, by R. V. Rhode, of the National Advisory Committee for Aeronautics, and a treatise on Fabrics Used in Aircraft Construction, by C. J. Cleary, complete this series of papers.

Amphibian and Seaplane Session

Amphibians and their design and maintenance are covered in two papers, one by Igor Sikorsky, designer of the Sikorsky amphibian, entitled, A Novel Method of Studying Flying-Boat Hull Models. This paper is based upon the work which Mr. Sikorsky carried on in the Housatonic River in Connecticut with towed models, the results of this research being somewhat unusual. The very important subject of Corrosion Prevention is treated in a paper by Lessiter Milburn, chief engineer of the Glenn L. Martin Co. This subject has been one in which a great deal of interest has been displayed, and Mr. Milburn's treatise was secured at the request of several of the leading airplane designers who meet with the problem of corrosion in the use of their product.

Aeronautic Chamber and S.A.E. Banquet

Thursday evening the joint banquet of the Aeronautical Chamber of Commerce of America and the Society will be held in the ballroom of the Book-

Meetings Calendar

National Meetings of the Society

19th National Aeronautic Meeting—April 15 and 16
Book-Cadillac Hotel, Detroit

Spring Production Meeting—May 7 and 8
Milwaukee; Sponsored by the Milwaukee Section

Summer Meeting—June 14 to 19
White Sulphur Springs, W. Va.

20th National Aeronautic Meeting—Sept. 1 to 3
Hotel Statler, Cleveland
In Conjunction with National Air Races

April Section Meetings

Baltimore—April 9
Lord Baltimore Hotel; Dinner 6:30 P. M.
Brakes and Brake-Lining—Alvin Yocom, Vice-President and Chief Engineer, Multibestos Co.

Buffalo—April 7
Hotel Statler; Dinner, 6:30 P. M.
The Romance of Rubber—V. R. Jacobs, Assistant Manager for Aeronautics, Goodyear Tire & Rubber Co., and Assistant Manager, Goodyear-Zeppelin Corp.

Canadian—April 15
Royal York Hotel, Toronto.
The Compromise in Motor-Car Design—C. E. Summers, Head of Special Design Section, Oakland Motor Car Co.

Chicago—April 9
Hotel Sherman; Dinner 6:30 P. M.; Entertainment
A Trip Through the West Indies and Along the Coast of South America by Airplane—Capt. A. W. Stevens, Army Air Corps, Wright Field.

Cleveland—April 20
Firestone Club House, Akron; Dinner 6:30 P. M.
The Future of Aviation—V. R. Jacobs, Assistant Manager for Aeronautics, Goodyear Tire & Rubber Co., and Assistant Manager, Goodyear-Zeppelin Corp.
Transportation Abroad—J. L. Cohill, Assistant Export Manager, Firestone Tire & Rubber Co.

Detroit—No Meeting
Omitted because of 19th National Aeronautic Meeting in Detroit in April

Indiana—April 9
Hotel Severin, Indianapolis; Dinner 6:15 P. M.
Subject: Lubrication

Metropolitan—April 16
A.W.A. Clubhouse, 357 W. 57th Street, New York City; Dinner 6:30 P. M.
Brakes and Their Relation to Highway Safety—David Beecroft, Bendix Aviation Corp., supplemented by several Motor Vehicle Commissioners from surrounding States

New England—April 8
Walker Memorial Building, M.I.T., Cambridge, Mass.; Dinner 6:30 P. M.
Traffic-Control Systems—C. A. B. Halvorson, Consulting Engineer, General Electric Co.
Traffic-Actuated Control—David L. Bacon, Research Engineer, Automatic Signal Corp.

Northwest—April 3
New Washington Hotel, Seattle, Wash.; Dinner 6:30 P. M.
Flame—Prof. F. G. Baender, Head of Mechanical Engineering Department, Oregon State College
Spark Analysis—C. C. Finn, Manager, John Finn Metal Works

Oregon—April
Multnomah Hotel, Portland; Dinner 6:30 P. M.
Cylinder Reconditioning—C. H. Stokke, C.W.S. Grinding & Machine Works
Correct Steering—Fred H. Carruthers, Bear Mfg. Co.

Philadelphia—April 8
Philadelphia Automobile Trade Association Rooms; Dinner 6:30 P. M.
What the S.A.E Is Doing Nationally—N. G. Shidle, Directing Editor, Chilton Class Journal Co.
Engineering the Operation and Maintenance of Motor Vehicles—H. B. Hewitt, Engineering Assistant to Vice-President in Charge of Operations, Philadelphia Rapid Transit Co.

Pittsburgh—April 9
Chamber of Commerce; Dinner 6:30 P. M.
Joint Meeting of the Section and the Pittsburgh Chamber of Commerce
Speakers: S. M. Kintner, Assistant Vice-President in Charge of Research, Westinghouse Electric & Mfg. Co.; Messrs. Hartwell and Gall, Aluminum Co. of America.

Southern California—April 3
Hotel Alexandria, Los Angeles; Dinner 6:15 P. M.
General Comments on Stress Analysis—Stanley S. LaSha, Chief Engineer, Western Office, Department of Commerce
Blind Flying—Major William C. Ocker, Kelly Field, Texas.

Washington—April 28
Hotel Washington; Dinner 6:30 P. M.
Address by Col. E. V. Rickenbacker, Vice-President, Fokker Aircraft Corp.
Developments in Aviation Spark-Plugs—G. M. Paulson, Chief Engineer, B. G. Corp.
Developments in Automotive Spark-Plugs—O. C. Rhode, Chief Engineer, Champion Spark Plug Co.

Wichita—April 10
Hotel Allis; Dinner 6:30 P. M.
Aircraft in the Navy—Lieut. L. D. Webb, U.S.N.

19th National Aeronautic Meeting Program

Book-Cadillac Hotel, Detroit — **April 15 and 16**

Wednesday, April 15

AIRCRAFT—10 A.M.

Commercial Flight-Testing—E. W. Rounds, Bureau of Aeronautics.

Fabrics in Aeronautics—C. J. Cleary, United States Army Air Corps.

AIRCRAFT DESIGN—2 P.M.

The Autogiro—W. Laurence LePage, Kellett Aircraft Corp.

Load Factors in Airplane Design—R. V. Rhode, National Advisory Committee for Aeronautics.

ENGINES—8 P.M.

High-Temperature Liquid-Cooled Engines—Arthur Nutt, Wright Aeronautical Corp.

Multi-Cylinder Low-Powered Light Engines—R. N. Dubois, Continental Aircraft Co.

Spark-Plugs—G. M. Paulson, B. G. Corp.

Thursday, April 16

AMPHIBIANS AND SEAPLANES—10 A.M.

A Novel Method of Studying Flying-Boat Hull Methods—Igor Sikorsky, Sikorsky Aviation Corp.

Corrosion Prevention—Lessiter Milburn, Glenn L. Martin Co.

AIRCRAFT FUELS—10 A.M.

Knock-Rating Session.

ENGINES—2 P.M.

Superchargers and Supercharging—Oscar Schey, National Advisory Committee for Aeronautics.

Bearing-Load Analysis and Permissible Loads—F. L. Prescott and R. B. Poole, United States Army Air Corps.

Airplane Fuel-Line Temperatures—Dr. O. C. Bridgeman, Bureau of Standards.

AIRCRAFT BANQUET—6:30 P.M.

Cadillac Hotel. No announcement can be made at this time as to the principal speaker, but the well-known humorist, "Senator" Ford, will have a place in the program. The price of the tickets will be $4, and tickets are available at the New York City office of the Society, except for Detroit members, whose applications for tickets should be sent to the Detroit Section office, room 2-136, General Motors Building.

All technical sessions will be held in the Crystal Ballroom and the Italian Garden at the Book-Cadillac and will start promptly at the times scheduled.

Spring Production Meeting in Milwaukee

THE FIRST spring Production Meeting to be held by the Society will be at the Hotel Schroeder in Milwaukee on May 7 and 8, instead of May 6 and 7 as announced in the March issue of the S. A. E. JOURNAL. In the main, the program has been arranged by Chairman J. R. Frantz and the members of the Milwaukee Section, the Meetings Committee of the National Production Activity Committee having cooperated in preparing the program for the technical session on the first afternoon. The first morning of the meeting is reserved for the registration of those who attend.

The first technical session in the afternoon will be devoted to the presentation and discussion of papers on the use of power-driven industrial trucks in handling materials in automotive manufacturing plants, with particular reference to interplant handling. The second paper will deal with the use of nickel alloys in production, as in die blocks. The evening will be devoted to a special meeting for which plans will be made by the Milwaukee Section.

The technical session on the morning of May 8 will be devoted to a paper on the surface hardening of steel and the effects of new developments on production costs. This will be followed by a trip to the plant of the Hevi-Duty Electric Co., where a demonstration will be given as a practical illustration of the paper. At the afternoon session the paper will deal with the use of new materials in high-speed milling, and this will also be followed by a demonstration visit to the local plant of the Kearney & Trecker Corp.

The meeting will be concluded with a Production Dinner arranged for by the Milwaukee Section on the evening of the second day. H. L. Horning, a Past-President of the Society who is well-known to the members, will preside as toastmaster, and a most interesting talk will be given by President Glenn Frank, of the University of Wisconsin, on the aspects of economical production as they affect present conditions.

As all of the plans for the dinner are being arranged for by the Milwaukee Section, those who expect to attend and desire to make reservations should communicate with J. R. Frantz, Chairman of the Milwaukee Section, at the Le Roi Co., Milwaukee.

The meeting has been planned by

Spring Production Meeting Program

Under Auspices of the Milwaukee Section

Hotel Schroeder, Milwaukee — **May 7 and 8**

Thursday, May 7

Morning—Registration of attendance

10:15 A. M.—Visit to automatic frame-plant, A. O. Smith Corp.

1:30 P. M.—Technical Session (National Production Activity Committee)

The Use of Power-Driven Industrial Trucks in the Handling Systems of Automotive and Automotive Accessory Plants—C. B. Crockett, Industrial Truck Association

Nickel Alloys in Automotive Manufacturing—T. H. Wickenden, International Nickel Co.

Evening—Feature Session (Milwaukee Section)

Friday, May 8

9:30 A. M.—Technical Session (Milwaukee Section)

New Developments in Surface Hardening of Steel and Their Effect on Cost of Production—H. E. Koch, Hevi-Duty Electric Co.

Demonstration at plant of the Hevi-Duty Electric Co.

1:30 P. M.—Technical Session (Milwaukee Section)

Latest Developments in High-Speed Milling with Tantalum and Tungsten-Carbide Cutters—F. W. Curtis, Kearney & Trecker Corp.

Demonstration at plant of the Kearney & Trecker Corp.

6:30 P. M.—Production Dinner (Milwaukee Section)

Toastmaster, H. L. Horning, President, Waukesha Motor Co.

Aspects of Economical Production as They Affect Present Conditions—Dr. E. A. Ross, University of Wisconsin.

the Milwaukee Section and the Production Activity Committee for the members and production men mainly in the Great Lakes region rather than as a general National Meeting such as the National Production Meeting that will be held in October as heretofore. The detailed program of the meeting is given herewith.

A Six-Day Summer Meeting

June 14 to 19 Will Witness Brilliant Gathering at White Sulphur Springs

SPECIAL trains from the East, special trains from the West and numerous automobiles from these and other points of the compass will roll into White Sulphur Springs, W. Va., on Sunday, June 14, bringing hundreds of S.A.E. members and guests to enjoy the hospitality of the Greenbrier Hotel and participate in the varied activities that make up a Summer Meeting of the Society. The meeting, which will continue until noon on Friday, June 19, will offer a comprehensive program of 15 technical and professional sessions, almost the same number of committee meetings and a pleasing variety of recreational features.

Programs for the sessions are being arranged by the eight Professional Activities of the Society, as well as by the Standards, Research and Meetings Committees; and the subjects to be discussed will be characterized by their timeliness and wide range. The Meetings Committee will announce the exact topics, together with the names of the speakers, in the next issue of the JOURNAL and in Meetings Bulletins.

Recreational events will have their place on the Summer Meeting schedule, so that everyone attending the meeting will have an opportunity to engineer himself through some form of non-engineering activity, whether it be golf, tennis or archery, a number of comic field-day antics, or a dive and a race in the swimming pool. Bridge and sightseeing will be arranged for the ladies, as in former years, and dancing will be enjoyed each evening after the adjournment of the technical session.

Committee Meetings Not To Interfere

Interference between one form of activity and another is all too likely to occur when so many events of so varied nature are crowded into one week. In an attempt to minimize such interference, the Meetings Committee has worked out a plan which seeks, in the terms of the old adage, to have a place for everything and everything in its place. According to the plan that has

(*Concluded on p.* 485)

Heldt Reviews Engine History

Improvements Made Shown at Buffalo Meeting by Comparing Early Designs with Present Engines

MEMBERS of the Buffalo Section, at their regular monthly meeting in the Statler Hotel on March 3, listened to a historical review of the development of the internal-combustion engine. This was presented by Peter Heldt, engineering editor of *Automotive Industries*, who was well qualified to deal with the subject, as he has been a student of and writer on this type of engine and on motor-vehicles for more than 30 years, having been technical editor of *Horseless Age*, the first automotive journal published in America.

Following the usual members' supper, Mr. Heldt gave his paper, which he introduced with the statement that the remark is sometimes made that no fundamental development in internal-combustion engines has been made since the earliest days of the automobile. While it is true that we still use gasoline and burn it in engine cylinders in the same way on the Otto-cycle principle, and all principal parts of the engine remain basically the same as in the pioneer automobiles, Mr. Heldt said that tremendous progress has been made in engine design.

Engines of 1895 to 1900

To bring out prominently the advances made in design, the speaker compared the engines of the experimental period of 1895 to 1900 with engines of the present day. In that early period, as old-timers in the industry can recall, most of the engines were of the horizontal type and had either one or two cylinders. This was partly because the pioneer "horseless carriage" builders followed the practice on stationary gas engines of the time, and also because they thought it necessary to place the engine under the seat of the vehicle and to conceal as much of the mechanism as possible so as to preserve the outward appearance of the horse-drawn buggy or carriage. Economic conditions also influenced the minimum number of cylinders, as the Country was only beginning to recover from the financial panic of 1892 and mail-order houses were offering buggies as low as $36, and good horses were selling, if at all, for less than $100 in the Middle West. As against these prices, the Winton and Haynes-Apperson automobiles were priced at $1,000 to $1,200.

Advances Made in Auxiliary Functions

Present engine designs, when compared with those of the early period, seem to Mr. Heldt to show greatest advances in connection with the four auxiliary functions: carburetion, ignition, lubrication and cooling. With carburetion he included control of the speed of the engine. Early engines were governed on the hit-and-miss principle, and were virtually constant-speed engines. Carburetion was by means of the so-called mixing valve in lieu of the later carbureter, and all early engines had automatic inlet valves that opened by suction of the cylinder on the intake stroke of the piston. Ignition was by means of the electric-spark make-and-break system, energized by a battery of primary cells, with no means for varying the spark timing prior to introduction of automatic timing in 1900 or 1901.

Lubrication was of the most primitive type, an oil cup of relatively large size being mounted on top of the horizontal cylinder to feed oil to the piston. The main bearings were fed by screw-down grease-cups and for lubrication of the crankpin bearing an oil-cup on top of the crankcase carried a wick from the end of which a quill on the head of the connecting-rod was supposed to pick off drops of oil and carry them through a radial hole to the bearing surface.

The radiator had not then been invented, and large tanks of water were carried above the engines from which the water circulated through the water-jacket by thermosiphonic action.

Engine speeds of the 1895 to 1900 period were seldom higher than 600 r.p.m. and a compression ratio of 4:1 was common.

Successive Changes Brought Troubles

Mr. Heldt than reviewed the many changes in engine type and improvements in functions down to the present time, mentioning the opposed-cylinder type, the vertical type, the increasing number of cylinders and the block type. Troubles arising from the larger number of cylinders and increased engine-speed resulted in introduction of aluminum pistons, sleeve valves, vibration dampers, quieter camshaft gears and chain drive to the camshaft.

Self-starters began to come into the picture about 1909. The earliest were of the compressed-air and acetylene types, the latter using gas from the acetylene tank used for lighting purposes. The electric starter came in 1911 and led to a return to battery ignition, displacing high-tension magnetos.

Airplane-engine development from 1915 to 1918 began to influence automobile-engine design, research work on the internal-combustion engine having been carried on intensively during the World War period and continued ever since. Weight per horsepower output began to come down, with increase in engine speed, compression ratio and brake mean effective pressure. Better materials of construction were also introduced, and antiknock fuels began to be demanded. Crankcase-oil dilution also gave trouble and had to be studied.

Power and Reliability Greatly Increased

By 1930 the 16-cylinder engine entered the automobile field and piston speed had been progressively stepped up from about 600 ft. per min. in 1895 to 2500 ft. per min. today. Horsepower for a given piston displacement has been multiplied by 5.35 and the engine weight per horsepower has been decreased from about 50 to about 10 lb.

With these many improvements, the reliability has been tremendously improved. In the early development of the Panhard car in France, Levassor set himself the task of covering a distance of 1 mile without involuntary stop, and after many attempts finally succeeded. By contrast, Mr. Heldt stated that in his recent experience a passenger-car has completed 50,000 miles without any engine trouble worth mentioning except some from rusting of the water-pump shaft; and in motor-coach operation at least 100,000 miles is expected without an engine overhaul.

St. Louisans Told about Car Features

NEW features shown in 1931 cars at the recent automobile shows were reviewed by five members of the St. Louis Section at the latter's meeting held on Feb. 10 at the Statler Hotel, with A. J. Mummert, of the McQuay-Norris Mfg. Co., in the chair.

Motor-truck features were outlined by G. C. Stevens, St. Louis branch manager of the Diamond-T Motor Car Co. George P. Dorris, of the Sterling Products Corp., spoke on engine trends and improvements and compared carbureter types.

Brakes and their application were outlined by J. C. Cox, Section Secretary, who pointed out brake changes caused by free-wheeling and increased car-speeds. Other mechanical features of the chassis were dealt with by V. Charles Kloepper, vice-president of

the American Metal Products; while George F. Heising, of the American Cotton Picker Corp., addressed the meeting on body construction and allied improvements.

The attendance at the meeting was 36.

Buses and Trucks Considered

Motorcoach Maintenance System and Truck Operating Problems Described at Chicago Section Meeting

EIGHTY members and guests of the Chicago Section enjoyed an excellent dinner at the Sherman Hotel preceding the technical meeting on March 3, and about 25 more came to hear the addresses after the dinner. Some unusual entertainment was provided during the dinner in the form of a singing and dancing number by a female entertainer, an acrobatic dance involving very difficult feats by a couple, and another very original acrobatic dance. All the numbers received hearty applause that indicated the approval of the spectators.

At the conclusion of the dinner and dancing, Section Chairman E. W. Stewart introduced A. J. Underwood, manager of the Sections department of the Society, who spoke briefly regarding the work the Society is doing and particularly about the Section activities. The chair was then relinquished to Vice-Chairman C. A. Pierce, who made some preliminary remarks about the subjects to be treated by the speakers of the evening. The first paper to be presented was on the subject of motorcoach maintenance and was prepared by G. Hind, of the Detroit Motorbus Co. Illness prevented Mr. Hind from attending the meeting but he delegated as his proxy Mr. Edwards, who presented the paper in a very acceptable way.

Detroit Company's Coach Maintenance System

Mr. Hind's paper covered the maintenance system used by the Detroit Motorbus Co., which operates approximately 400 vehicles. These operate from five garages and travel about 13,000,000 miles per year. A fleet of this nature calls for a maintenance system that at all times must be adequate, efficient and economical, and that is based on "eternal vigilance" as well as on records. The buses are scheduled for inspection after every 2500 miles of operation and are then placed over well-lighted pits for this purpose. The history of the bus at this time enables the foreman to determine the amount of work necessary to put the vehicle in first-class condition.

The paper explained in detail how all units are serviced and lubricated. If good maintenance practices are exercised at certain intervals, it is natural to assume that the chassis always remains in first-class condition, according to the author.

The question of exhaust odors inside of the vehicles was extensively discussed by some of the members and evidently is one of the serious problems which must be overcome.

Truck Design for Economy

The next speaker was J. F. Winchester, superintendent of maintenance for the Standard Oil Co. of New Jersey, who gave an extemporaneous talk on transportation, illustrating it with slides. In this way the engineering progress in motor-truck and body design was clearly brought out. One of the main points made was that transportation problems should be thoroughly analyzed and proper equipment specified. In some cases trailer equipment would be more economical to operate than trucks and vice versa.

The subject of tires was discussed and the fact was brought out that pneumatic tires have important advantages over solid tires; in fact, Mr. Winchester stated that the company he represents is replacing solid tires with pneumatics as fast as the old ones wear out.

Slides showing large semi-trailers equipped with aluminum bodies were shown. These bodies have been quite satisfactory from a service standpoint. They have been in operation several years and show considerable promise. Much can be accomplished with bodies of this type, greater payloads being carried, thereby decreasing transportation costs.

A novel type of frameless semi-trailers with tank bodies was also shown. The body is designed to have the springs and axles mounted on it. Thus the payload is increased and transportation costs reduced.

The transporting of gasoline involves other problems, such as fire hazard, and safety valves and fittings must be employed. These are all approved by the laboratories.

In operating 17,000 vehicles, said Mr. Winchester, the maintenance work must be thoroughly organized. The types of service station and equipment used and the methods followed were illustrated and explained. Some pieces of equipment showed a saving of nearly 40 per cent, which is an important item when operating such a large number of vehicles.

A lively discussion followed, which drifted into motor-truck ratings. This is a complicated subject and the thought was that a paper on it should be presented at some future meeting of the Section.

The next meeting is to be held April 9, when the subject will be A Trip through the West Indies and along the Coasts of South America by Airplane. It will be presented by Capt. Albert W. Stevens, of Wright Field.

High-Speed Diesels in Sight

Instructor at M. I. T. Reviews Development, Lists Advantages and Demonstrates Operation

THAT high-speed Diesel engines are in sight was the assertion made by Myron S. Huckle at the March 11 meeting of the New England Section, in the Walker Building at the Massachusetts Institute of Technology. It was the largest meeting of the season, with more than 300 present, a large number being M. I. T. students. Mr. Huckle, who is an instructor at the Institute, predicted such engines running at 3000 r.p.m. He stated that Diesel-engine builders, with few exceptions, seem content to continue along the lines of least resistance instead of pushing forward to meet present demands. He amplified his talk with many lantern slides that gave substance to his claim. These slides recorded all sorts of tests made at the Institute and at Langley Field, Va., by which comparisons can be made.

Safety will be a big factor in bringing about the use of the high-speed Diesel engine, stated the speaker. Pictures of all types of Diesel engine made here and abroad for use in airplanes, trucks and motorcoaches were shown.

The London General Omnibus Co., seeking high-speed engines, found no company prepared to build them, so it is building 100, of which 25 are to be sent to the United States. Germany is attacking the problem, too, but, with the high duties in this Country, it is not very profitable to sell them here, the members were told. Mr. Huckle referred to the Packard Diesel aircraft engine and showed pictures of it, pointing out various features. On his final chart, where it was one of about 15 Diesel types, it ranked above the others, according to the speaker.

In his analysis of the advantages of the high-speed types, Mr. Huckle divided these into safety and economy. Safety was divided into sub-sections re-

volving around fire hazard, radio interference, multiple fuel system, simplified control, and general operating safeguards. Under fire hazard he classed operations in which safety would prevail, as in the air, in crashes, on the ground, in marine work, and fuel distribution. From that he went on to show advantages in radio, indifference to weather from air and fuel mixture, and resistance to overheating. Operation safeguards pointed out are wide firing limits, excess power for use in emergencies, better acceleration, dependable starting, freedom from vapor lock in fuel lines, no inflammable gas in the exhaust manifold to ignite in case of spark failure, and so forth.

Economy is realized through the use of cheaper fuel, including waste mineral oil and animal or vegetable oils as is done abroad, reduction of insurance, increased range and performance, perfect mixture, altitude adjustment and other features. Reliability is given through the fuel not freezing as readily as does benzol, the absence of a delicate high-tension electrical system, and some of the other things listed under safety, Mr. Huckle told his audience.

With charts he showed clearly three general methods of getting good combustion: through a directed spray, by a precombustion-chamber and by induced turbulence. He pointed out the advantages of some and disadvantages of other types of combustion-chamber, and spoke of the fundamental requirements of good combustion, such as full utilization of all the air by design of the fuel nozzle for accurate fit, plus high turbulence. Structural problems also were touched on.

Air-Cooled Cylinder Demonstrated

When the address was over the audience went to the aeronautic-engine laboratory, where they saw an air-cooled Diesel cylinder running at 2000 r.p.m. Mr. Huckle started it and, while it was running, described some of the things that can be done with it.

Talking with some of the S. A. E. executives after the meeting, Mr. Huckle said he was interested to read that a Diesel-engined car had been entered in the Indianapolis 500-mile race to be run in May, and predicted that the car would continue through to the finish, although it may not win the race. To him it was an indication that some people in this Country are willing to work for the high-speed type of engine. He also recalled the trip of Mr. Cummins from Columbus, Ind., to New York City a year ago in his Diesel-powered car, and the remarkable performance it made.

Previous to the address, Chairman Albert Lodge, who presided, asked for a report from the Nominating Committee on Section officers to be elected next month to carry on the work for the 1932 season. Chairman M. F. Wolfard, of the Committee, reported nominations as follows:

R. F. Lybeck, Chairman; Dean A. Fales, Vice-Chairman; Fred W. Herlihy, Secretary; A. E. Postal, Treasurer. These names will be voted on at the April 8 meeting, which will be devoted to traffic signals.

A. J. Underwood, manager of the Society's Sections Department, was presented and stated that within a few weeks the Society will have 23 Sections operating in this Country and Canada. The membership of the Society is now more than 7000, not including 300 enrolled students, he said.

Professor Hamilton, of New York University, is so interested in the subject of high-speed Diesel engines that he flew over from New York City to attend the meeting and took the midnight train home.

Steering Troubles Explained

Two Speakers Tell Pittsburgh Section about Front-End Misalignment and Tire Wear

MEMBERS and guests of the Pittsburgh Section to the number of 126 attended the Steering-Gear Alignment Meeting on Feb. 26, and 89 enjoyed the dinner immediately preceding the technical session. As an emotional after-dinner stimulus and fitting introduction to the subject, Why Automobiles Shimmy, various kinds of oriental acrobatic dancing were demonstrated by Mary Ann and her friends, together with some genuinely good singing that was much appreciated.

Section Vice-Chairman B. H. Eaton, of the Bell Telephone Co., conducted the election of members of the Nominating Committee, Prof. J. W. Trimmer again being elected Chairman of that Committee. Others elected as members of the committee were Gibson W. Brown, of the Bell Telephone Co.; Joe A. Harvey, of the Pittsburgh Motor Coach Co.; Nils G. Bjorck, of the Lange Motor Truck Co.; and John M. Orr, of the Equitable Auto Co.

Joseph L. Pasher, of the Wagner Electric Corp., then assumed the duties of Chairman and called attention to the motion pictures, the first of which showed the comparatively negligible effect that shooting a hole through one of the front tires of a motorcoach travelling at 60 m.p.h. had on a sturdy and correctly adjusted steering-gear. The second motion picture showed the effect of driver psychology on steering.

Attention was called to the convenient little "note-book" provided for each member in which to write questions to be asked at the conclusion of the meeting.

Mr. Pasher then introduced the first speaker, A. R. Platt, a Pittsburgh man who is a member of the Steering-Gear Division of the Society's Standardization Committee and has been one of the pioneers in the elimination of steering-gear troubles. In addition to his active work in checking the steering-gear alignment of many thousands of cars each year, Mr. Platt is a member of the faculty of the automotive department at Carnegie Institute of Technology in Pittsburgh.

In his address, Mr. Platt discussed the properties that constitute a good steering-gear, those that are undesirable, and the relation of steering-gear design and service to steering quality and tire wear. A good gear may not produce good steering because of a poor axle-assembly, he said, whereas a good axle-assembly may be ruined as regards car handling by a wrong steering-gear. Remarkable tire mileage may be obtained with a good axle and a poor gear, but the car will be hard to handle. On the other hand, a car that feels easy to handle may be punishing the tires severely. Certain axle defects are evident in the handling of the car and consequently usually receive the most prompt attention. Unfortunately, many steering defects develop so gradually that the driver is not conscious of them and are revealed only by the rapid wear of the tires.

In general, correction of faults that affect tire wear usually improves the steering quality, but corrections for steering quality may or may not affect tire wear. Camber, caster, toe-in and turning radius of the front wheels are the four major factors affecting the axle set-up, said Mr. Platt. The steering troubles most frequently encountered in service were listed by the speaker.

Strong Axle-Assemblies Hold Adjustments

Research work done by a subcommittee of the Society, said Mr. Platt, showed that less than one-half of 100 cars tested met the manufacturers' specifications as regards steering mechanism at the time of delivery. And after these cars had been adjusted to meet the specifications, a large percentage did not maintain the settings for 1000 miles of driving, but those which had structurally strong axle-assemblies held the settings within fairly close limits for several thousand miles of service. The parts most affected in the first 1000 miles are ball joints, front springs, rims and so forth. Camber of the wheels should not change.

After a new car has been worn in and the steering parts reset, any further errors requiring correction must be the result of unusual wear or abuse, according to Mr. Platt. Road shocks may alter the camber, caster, toe-in or turning radius by slightly bending the axle ends, the steering arms or the tie-rod. Grabbing front brakes may twist the axle ends. Every time a front spring is altered or replaced, the caster should be checked, as a change in caster affects the turning radius and the toe-in to some extent.

Almost all of nearly 5000 cars checked by Mr. Platt in the last 2½ years had some front-end trouble that caused excessive tire wear and about 75 per cent had errors that seriously affected the steering quality, the commonest trouble being shimmy. Three requisites for proper correction of steering errors are: (*a*) knowledge of the fundamental principles involved, (*b*) suitable shop equipment and (*c*) ability to use the equipment correctly to make it serve the purpose for which it is intended.

Causes of Excessive Tire Wear

The second paper on the subject was presented by A. E. Feragen, of the Motor Wheel Co. He dealt first with tire-tread wear, saying that under-inflation is the chief contributing cause. The next most important cause of bad steering and consequent tire wear is incorrect wheel toe-in.

Mr. Feragen explained how even a slight misalignment of the front wheels causes lateral thrusts that result in rapid wear on the large area of tire tread in contact with the road surface. Also by means of lantern slides he showed the effect on the tires of excessive wheel camber, error in the degree of steering angularity or geometry, uneven caster and other factors. How these various things and others affect steering and cause front-end phenomena, such as shimmy and kick-back, was also explained.

The address was concluded with a description of methods followed in good practice to correct the various steering troubles. The manufacture of steering-gears has been greatly improved in the last year, said Mr. Feragen, so that not nearly so much trouble with kick-back and high-speed shimmy will be encountered in the 1931 cars as in former years.

Periodic Checking Saves Tires

An unexpected but welcome addition to the program was an explanation by a member, A. C. Haller, of the Haller-Hirth Sailplane Corp., of the tendency of some cars to "dive" into corners. He likened the car to a roller skate and the way in which tilting causes the roller trucks to change their radius due to the caster at which these rollers are mounted.

As experience has shown that careful checking of steering alignment every 500 miles results in increasing the tire mileage of motorcoach fleets from 400 to 500 per cent, resulting in more reliable operation as well as large savings in tire cost, the members of the Pittsburgh Section agreed that the subject had been well worth the evening spent on it.

The next meeting of the Section is to be on April 9, in connection with the Pittsburgh Chamber of Commerce, and is expected to be a particularly good one, with addresses by representatives of important local industries.

Research May Influence Laws

Improved Accelerometers Described at Indiana Section Meeting—Shock-Absorber Characteristics

STEPS by which the riding-comfort research has advanced and the development in instrumentation and the measuring of riding comfort were described by Roy W. Brown at the Indiana Section's March 12 meeting in Indianapolis. Mr. Brown, who is in charge of the engineering laboratories of the Firestone Tire & Rubber Co., is Chairman of the S.A.E. Riding-Comfort Subcommittee of the Research Committee. Fred E. Ullery, of the research department of the Studebaker Corp. of America, also presented a paper entitled, Shock-Absorber Characteristics. The meeting was attended by 150 members and their friends.

In giving a summary of what has been accomplished by the riding-comfort research by various organizations, Mr. Brown covered the high points of the entire research and showed 40 lantern slides that graphically portrayed the advances made in instrumentation and in attacking the problem from many angles. He said in part:

> Weight-spring accelerometers which were used until a few years ago did not prove practical due to the error resulting from the natural period of the instrument approximating the period of the acceleration being measured. Finally, the evolution of the contact-type accelerometer in the Firestone laboratories was followed by modifications and advances of the new principle and these were rapidly developed into practical and accurate instruments suitable for continuous road service.
>
> The substitution of the solenoid for the spring removed the last remaining objection to the use of the contact instrument. Then specially developed electrically operated counters were substituted for recording devices; and these, together with the new-type accelerometers, now give us the means for determining at the end of the test run the total number of accelerations and their magnitude. This recording device has made possible the determination of accelerations occurring over long runs where the total count may run into hundreds of thousands. The micrometer-contact type has been developed into a ten-unit-element recording instrument by the United States Bureau of Public Roads and has operated very satisfactorily during the last year.

May Soften Legislative Attacks

This development, it was hinted, may give the industry and the whole automotive world some very new and valuable data on the moot subject of good roads and the alleged "abuse" of modern roads, which has subjected the industry, particularly the commercial-vehicle branch, to constant attack during the recent legislative sessions in various States. The older methods of measuring road abuse and impact by instruments that are regarded as obsolete exaggerated the damage that even a heavily loaded truck might cause to a road. Recent progress in measuring accelerations shows clearly, according to Mr. Brown, that the higher the obstruction is over which the wheels of a vehicle pass, the greater is the force of the impact; that it progresses upward exceedingly rapidly as the height of the obstruction increases and that even such variations as ¼ in. enormously increase the blow. We know now that if a road were perfectly smooth a heavily laden vehicle even on steel tires would cause virtually no damage to the road with the normal maximum weight limits. The newer instruments now in use may have the possible effect of causing less drastic truck-weight limitations to be worked out, and this may aid in softening the legislative attacks leveled at the industry.

The ultra-high-speed motion picture shown by Mr. Brown of tire action at speed as the wheel passes a road obstruction clearly showed how the low-pressure pneumatic tire hugs the road and the road obstruction, whereas the solid tire clearly jumps and continues to dance for some time after passing the bump. It is possible that truck makers in the future may have such pictures taken of their heavily laden trucks running on balloon tires and display them to hostile legislators who have been giving sturdy aid to the attacks of some of the railroad interests. Though Mr. Brown carefully refrained from such inferences, some of the members present who knew about the recent Indiana legislative attacks on trucks and sane truck limits were of this opinion.

Studies of Fatigue and Discomfort

Now that measurements of accelerations have been developed and advanced until they give accurate results,

continued Mr. Brown, it remains to determine the physical and mental effects of the accelerations, vibrations and noises that enter into the comfort equation. This portion of the work is in the hands of Dr. F. A. Moss, of George Washington University, whose efforts have been concentrated upon finding an objective measure of fatigue that would be reliable and free from subjective error. Dr. Moss's investigations along this line have been fully reported from time to time in the S.A.E. JOURNAL during the last two years. They led to the invention by him of the wabblemeter, illustrated on p. 251 of the February, 1931, issue and described on p. 252. This instrument, as developed and perfected by the Firestone Tire & Rubber Co., is now commercially available to other investigators.

Prof. Ammon Swope, of Purdue University, is attempting a statistical study of passenger reactions to such items as seat cushions, upholstery, speed, tire noises—which, by the way, he finds that they like—and similar items. In conclusion, Mr. Brown said that "the relative discomfort factor varies in proportion to the square of the accelerations at accelerations above 4 or 5 ft. per sec. per sec. It now develops upon the engineer to put into use the advances that have been made by the riding-qualities research of the Society."

Following Mr. Brown's paper, Mr. Ullery gave a very comprehensive paper on Shock-Absorber Characteristics, illustrated with a score of lantern-slides.

The discussion following the papers was limited, because of the time element, but Professors Swope and Jacklin, of Purdue, gave brief side-lights into that part of the research which has been under way at the University and exhibited some of the Purdue instruments used in the work. These, with a wabblemeter which Mr. Brown had brought, created considerable interest and held part of the audience almost an hour beyond the regular 10 p. m. closing hour of the meetings.

In a brief business session at the end of the dinner, the report of the Nominating Committee for Section officers for next year was read by Chairman Charles Merz, as follows:

Chairman, H. M. Jacklin, associate professor of automotive engineering and research associate, Purdue University; Vice-Chairman, Louis Schwitzer, president of the Schwitzer-Cummins Co.; Treasurer, Charles A. Trask, efficiency engineer of the Rockwood Mfg. Co.; Secretary, Harlow Hyde.

Advances in 1931 Cars

Improvements Pointed Out to Cleveland Section by Harold Blanchard—Legislation Discussed

NEW 1931 automobiles, proposed State legislation, the Goodyear Zeppelin and the Tatra six-wheel automobile all served to contribute to the success of the Cleveland Section meeting at the Hotel Statler on March 9. Section guests included a large number of members of the Cleveland Automobile Dealers and Manufacturers Association, who were specially invited because of the wide interest of the subjects.

Fred H. Caley, secretary of the Cleveland Automobile Club, delivered the searchlight talk on the subject, What Ohio Should Do for the Motorist. He advocated the adoption of legislation covering the development of an adequate State police organization, the adoption of a drivers' license law, and a system whereby an owner might receive a certificate of title to his car and thereby obviate all bills of sale, sworn statements of ownership and such troublesome details that the present system brings about. The speaker also stated that there should be no further increase in the gasoline tax. At current prices the tax of 4 cents per gal. represents from 20 to 25 per cent of the price of the product.

A. E. Bronson, meeting sponsor, introduced Harold F. Blanchard, technical editor of *Motor*, as being a true "old timer" in the industry. Mr. Blanchard's talk was on the subject, New Engineering Features in 1931 Cars. Prepared discussion on this subject was given by O. A. Parker, of the Parker Wheel Co., and A. J. Scaife, of the White Co.

New Cars Cheaper and Better

The two most important changes in the new cars were said to be in the greatly improved transmissions and in the generally decreased prices. This year the average cost of a five-passenger four-door sedan is $1,788, as against $1,953 for 1930. This reduction has been brought about through lower material cost, improved production methods and a decrease in profit margins. Also, the fact that many manufacturers are using the same or only slightly modified body styles as last year, or else are using the same bodies on different chassis, has helped materially in lowering prices.

In spite of these lower figures, the quality of this year's car is relatively higher, dollar for dollar, than ever before. The principal factors in this are larger or more powerful engines, improved fuel economy, greater smoothness and quietness, greater reliability, easier steering and gearshifting, higher speed, and more comfortable and better bodies. These improvements have been accomplished without radical changes in basic designs. Chassis and bodies have been gone over carefully and improvements and changes made almost entirely by way of refinements rather than in fundamental principles.

In appearance, probably the most noticeable change is in the almost general adoption of radiator shutters or grilles. The former of these has a very definite value, said Mr. Blanchard, whereas the latter is of questionable utility and is possibly only a passing fancy. Another trend is shown in the adoption of a broad-shouldered tapered-waist type of radiator shell, usually with a rounded base.

In general, three things have been done to make bodies quieter: First, frames have been redesigned with deeper channels and better cross-members; second, the cowl and windshield-pillar units have been more strongly braced; third, panels and seat frames have been sprayed with sound-deadening material.

In engine design, the most important improvement relates to quietness. This is accomplished through the use of rubber mountings and insulation and by the adoption of intake silencers. There has also been a continuation of last year's trend toward more cylinders, and there has been a slight increase in both piston displacement and compression ratio.

Synchronous-mesh transmissions are found on seven makes; three-speed transmissions with quiet second on twelve makes, and four-speed transmissions with silent third on four makes.

Transmissions and Free-Wheeling Discussed

Free-wheeling and its advantages were thoroughly discussed by Mr. Blanchard. The most important of the advantages were said to be: (*a*) easy, silent gearshifting; (*b*) the thrill of coasting whenever the throttle is closed; (*c*) greater fuel and oil economy; (*d*) reduced wear on the engine and driving mechanism; and (*e*) less tendency for the rear wheels to skid in turning a corner, as the full traction of the wheels is available to resist sidewise motion. Against these advantages were considered the disadvantages of (*a*) more frequent operation of the brake pedal; (*b*) noise contrast which exists when the engine is brought up to speed after free-wheeling; (*c*) the increase in idling speed, which is required in order to prevent stalling while free-wheeling; and (*d*) the operation of the free-wheel principle involves a new technique which the operator must learn.

Automatic clutches and infinitely variable transmissions were also discussed by the speaker.

In the discussion which followed this paper, it was pointed out that many of these refinements or improvements of 1931 have been of such a nature as to make the construction more complicated, and, as such, should be viewed with caution by the industry. The need of a new type of power transmission that will replace the gearset entirely was pointed out.

The possibility of changes in spring suspension was also discussed. The conventional method of mounting the springs today is essentially the same as it was on the horse-drawn carriages, whereas a possible improvement might be accomplished by adopting another type of spring suspension. The four most successful car manufacturers of 1930 were successful, it was said, because their products were distinctly different from others.

Motion pictures were shown of a truly different car, the Tatra, manufactured in Jugoslavia, which is of six-wheel frameless construction, with independently sprung rear wheels. This was described by A. T. Colwell, of the Thompson Products Co.

A film showing the construction of the new Goodyear Zeppelin was run to arouse interest in the Section's trip to Akron on April 20, as guests of the Akron members of the Society.

Oregon Section Looks Ahead

Frank Skipper Analyzes Leadership and Professor Baender Reviews Car Designs of 1931

BY FAR the most largely attended meeting of the 1930-1931 season so far held by the Oregon Section was that of Feb. 12 at the Multnomah Hotel in the week of the annual Portland Automobile Show. It drew an attendance of more than 140, many of whom were automobile dealers from all parts of Oregon. Among the notable guests were Commissioner-Elect R. E. Riley, representing the Civic Emergency Committee; Roy Burnett, representing the Oregon State Motor Association; A. L. Fields, president of the Portland Automobile Dealers Association, and George L. Sammis, president of the Oregon Chapter of the National Aeronautic Association.

Automotive Industry in Portland

In an address at the opening of the banquet, Mr. Riley said in part:

Some idea of the importance of the automotive industry to Portland and the surrounding territory can be obtained from the fact that this industry is represented by some 1000 establishments having a total investment of nearly $40,000,000 and employs about 7000 people. Here the industry is concerned almost entirely with the phase of operation, and in keeping with that I have noticed that your programs have dealt very largely with service problems.

That the Oregon Section will be of great benefit to the industry here has already been amply proved by many undertakings you have successfully completed, but before closing I wish particularly to commend you for the splendid gift you made to the Oregon State College at the last meeting in the form of an airplane fuselage and other parts.

Speaking as the representative of the State dealers' association, Mr. Burnett remarked that those who are in the business of selling automobiles have been haunted heretofore by the possibility of the announcement of a new model every few months, and that one of the biggest forward steps recently made by the industry is the adoption by the manufacturers of the policy of announcing new models only in the last two months of the year. This policy will have a very steadying influence on the whole of the automotive industry, he said, and should have been adopted long ago.

Prof. F. G. Baender reviewed the changes that have been made in cars for this year, discussing each of the major car units and predicting tendencies in design in the future. He said that last year 60 per cent of the car models were built with six cylinders or less and only 40 per cent with more than six. This year 60 per cent of them have more than six cylinders, and he predicted that the future will see a still further increase in the average number of cylinders per car.

The Art of Leadership

Frank H. Skipper, personnel director of the Pennzoil Co., spoke on the art of leadership. He said in part:

The future of our business and yours is not controlled today by the thinking of a handful of executives but by the total volume of thinking done by every human unit. The essence and spirit of leadership is thinking and teaching to think, to stimulate the individual to the joy there is in thinking, the profit there is in thinking about his job, about industry, about everything that can add to his skill or to his happiness. We must keep in view at all times the fact that the greatest single factor in efficiency is personal happiness, because a person in a happy state of mind can see a thousand things to aid him in his job to which the troubled mind is utterly blind.

To us the study of the art of leadership is a problem of four sides: the art of selection, the art of instruction-inspiration, the art of correction and the art of research.

The keynote of selection is the discovering of character, which is more important than that a man have the right technical qualifications. It is the greatest asset a business can have. That company makes big dividends which, through the selection of its individual employes, builds up a composite character of high standing.

The most vital time for a new employe is the first day he joins an organization. If his best side is not reached at that time, the dividends he can earn for us and the pay he can earn from us will be lessened. The least that can be done for him is to supply him with a record of all past experiences on the particular job he is to fill. Then point out to him that almost every previous holder of that job has improved it and that it is given to him as a trust to improve it still farther.

The keynote of the art of correction lies in a very careful analysis of the motive that produced an error. If the motive was a good one, the error was one of judgment. All the good in the world has come through analyzed errors, and this is the only road to improvement in business and personnel. If the motive really was bad, there is only one remedy. No business can put up with people who do things with bad motives, and the sooner they are cleaned out the better for them and the better for the business.

I am not sure but that the art of research is the greatest of the four cornerstones of leadership. Not research with a motive for increasing profits, but research to save space, time, energy, materials and labor, with the object of passing on to the consumer the advantages of the economies effected.

S.A.E. Contributes to Better Service

Speaking for the Portland dealers' association, A. L. Fields asserted that the intelligent operation of a service department is as important to the retail dealer as is the intelligent operation of a sales or an accounting department. It might seem an easy task to find a service man, but an efficient service man must have more qualifications than any other department head in retailing. Besides being thoroughly acquainted with the mechanics of an automobile, he must have a knowledge of accounting systems, be able to select and oversee mechanics, and be a high-class salesman, because it is in his line of duty to meet, sell to and satisfy his firm's customers.

Largely through the work of the Society, he said, the several departments have been brought so closely together that in a great many instances the sales department has supervision over the service department. The Society has introduced intelligence into present-day automobile service organizations, he continued, and the retail organizations are most thankful for this. They feel that the S.A.E. is largely responsible for the degree of efficiency that is now found in the industry.

Diesel-Engine Development Reviewed at Syracuse Meeting

THE MARCH 11 meeting of the Syracuse Section was opened by the showing of two reels of motion pictures illustrating the construction and testing of all-steel bodies. Following a talk by Chairman E. S. Marks on the forthcoming Summer Meeting, pictures taken at the 1930 Summer Meeting were also shown.

The speaker of the evening was Harte Cooke, chief engineer of the McIntosh & Seymour Co., of Auburn, N. Y., and his topic was Diesel-Engine Development, a branch of the industry with which he has been in personal touch for some 30 years. In 1900 Mr. Cooke had the unusual privilege, he said, of going through the Krupp plant in Germany, and not long afterward saw some of the early models of Diesel engines developed at the Krupp plant for stationary work. The first of these were of single-cylinder design but were not of rigid enough construction. The next models were built more solidly and promptly blew up, but before long a simple air-injection engine was developed and found practical.

The development of the Diesel type in Europe was stimulated by the high cost of fuel. After the first tests, it was found that considerable additional saving was made in the time required to start the engine and in the amount of labor and maintenance needed.

Forty-seven slides were shown to illustrate the construction and use of various types of Diesels designed for stationary, locomotive, marine and submarine use. Heavy-oil engines have almost entirely superseded steam engines in ships that are being built today, according to Mr. Cooke. Considerable weight and fuel space are saved and the old engine-room with its intolerable heat has been abolished.

In all types of work Diesel engines have been found easier to cool, since they throw off considerably less heat than gasoline engines and so bring about a reduction in radiator problems.

Reasons for Automotive Development

In America little thought was given to the Diesel engine for automotive use until the last few years, when higher road-speeds for large trucks and motor-coaches made necessary considerably more sturdiness and weight. These vehicles required greater horsepower and the larger investment in them caused operators to endeavor to get more use out of them and so spread their depreciation and capital expenses. When the trucks and coaches began to be used more hours per day, said Mr. Cooke, the cost of fuel became a second great consideration, and every method of lowering the fuel cost was investigated.

The development of Diesel engines for aeronautic use has been one of the consequences of the search for engine types that will produce an extremely high ratio of horsepower to weight. The Diesel has also been found to be considerably safer than the gasoline engine because of the low inflammability of the fuel oil used. Present problems for Diesel engineers are the standardization of fuel, study of the exact process of ignition and combustion within the engine, and measurement of the time elapsing between entry of the fuel into the cylinder and its ignition and between ignition and the finish of combustion.

Eighty-seven persons heard Mr. Cooke's talk and 22 attended the dinner in his honor which preceded the meeting.

Grinding Speeds Up Industry

Making and Use of Grinding-Wheels Described and Pictured for Northwest Members

THE NORTHWEST Section greeted John A. C. Warner, Secretary and General Manager, at its regular meeting held March 11, in Seattle, at the New Washington hotel. The visiting official from the National body addressed the gathering on the organization, plans and purposes of the Society and exhibited motion pictures of President Vincent Bendix, the Vice-Presidents and members of the Council. This was the first showing of the film and served as an introduction of the officers to the Northwest membership.

The technical paper presented was on Grinding-Wheels for Industry, with Arthur W. Cox handling this subject. He is factory representative for the Norton Co., of Worcester, Mass. Following his general résumé of grinding-wheel manufacture and usage in relation to developing "the age of speed," Mr. Cox displayed interesting motion pictures showing the making and application of grinding equipment and its relationship to all industry. The pictures were exceptionally interesting considering the mechanical or industrial nature of the subject, being made so by interjection of interesting sidelights and background of allied industry.

Don F. Gilmore, Section Chairman, announced that the next meeting is to be in Seattle on April 3, when Professor Baender, of the Oregon State College, will give his long-sought address on Flame. The following day delegations will go to Vancouver, British Columbia, for a special meeting at the invitation of Roy Howard, of Roy Howard, Ltd., which conducts an automotive service business in the Canadian city. This will be the first international S.A.E. meeting held in the West.

The Nominating Committee, through Chairman Robert S. Taylor, reported nominations for officers of the Section as follows: for Chairman, C. H. Bolin, of the Pacific Telephone & Telegraph Co.; Vice-Chairman, James Frinck, of the Washington Iron Works; Secretary, John Holstrom, of the Kenworth Motor Truck Corp., and Treasurer, Charles Finn, the present incumbent. Mr. Bolin has served capably for the last year as Secretary. All the nominations were unanimous in committee. The new officers are to be elected at the next meeting.

Vice-Chairman Al Jones briefly reviewed the growth of the Northwest Section since its inception two and one-half years ago. Leadership and support are two requisites for any organization to prosper, he declared, and both had been found in this Section. The Oregon Section sprang from the Northwest Section, and Vancouver, B. C., and a Spokane, Wash., Section are possibilities of the future.

H. W. Drake, Chairman of the Oregon Section, gave a short talk.

Keen interest in what the distant Northwest Section is doing is taken each month by the men at the helm of the National Society, declared Mr. Warner. He explained the monthly Council meetings at which the 18 men, who are leaders in their fields, discuss matters pertaining to the automotive industry and to the Society. He complimented the local officers for the work they are doing and stated that to get up interesting programs for each meeting is no small task.

Grinding-Wheels Become Precision Tools

Mr. Cox, in his address, pointed out the important part played by grinding in permitting of high speed in machinery due to research work, which has developed abrasives to grind within tolerances of 0.0001 in., this being common. He first explained the composition of grinding-wheels and how they are made into precision tools serving modern industry.

Shipment of the aluminum-oxide ores from mines in Arkansas to Niagara Falls for electric fusion and thence to the Norton factory at Worcester, Mass., for fabrication in the making of Alundum wheels was described. For the grey Crystalone wheels, silicon carbide, a manufactured product of coke, salt, carbon and other material, is used, this type being used specially for metals of low tensile strength.

Development of B-bond in recent years as a binder was explained. This is a strong binder, stated Mr. Cox. It is flexible and withstands a temperature of 500 deg. fahr., is dense and of fine finish, hence is suitable for use in lapping. An important characteristic of B-bond is that it has the same coefficient of expansion as the abrasive. Thus, as heat develops, it expands both the grains and the binder without distortion and the wheel holds a sharp cutting-face. In some degree this binder is in itself an abrasive, being a

glassy binder, said Mr. Cox, and as the wheel wears down evenly, the structure remains the same. This is a white wheel, looks like sugar and "grinds just as sweet."

The grade or temper is the hardness and depends upon the binder, the abrasive and the pores or voids, stated the speaker. Controlled structure, he declared, is the most important forward step in years. This permits exact duplication, so wheels can be reordered with elimination of undue variables, a thing impossible before controlled structure was evolved. "High-speed grinding makes possible the automobile of today," asserted Mr. Cox. "Also it makes possible the price of today. Now a crankshaft can be turned in minutes better than in hours a few years ago. Controlled structure means 'tailor-made' grinding and replacement exactitude."

The No. 1 problem in grinding is speed, continued the speaker. The best set-up for the work always requires the proper speed. A mile a minute on the rim is the accepted average speed. The grinding-wheel must be visualized as a tool, and the industry is trying to keep abreast of new metals. Greater preciseness, more severe tolerances and new metals such as Carboloy force the industry to study new methods, and engineers are always alert to these requirements and developments.

Then followed the showing of the grinding pictures, portraying visually some of the points the speaker made in his paper.

Safety Conference in New York

Important Commercial-Vehicle Session at Meeting Sponsored by National Safety Council Engineers

THREE important papers were presented at the commercial-vehicle session of the second annual Greater New York Safety Conference held Wednesday, Feb. 25, at the Hotel Pennsylvania, New York City, under the auspices of the Metropolitan Chapter of the American Society of Safety Engineers and 40 cooperating organizations including the Society of Automotive Engineers. Henry J. Mineur, of The Borden Co., was chairman. In his opening remarks he stressed the necessity for getting motor-vehicle traffic over the road safely.

Lieut. Edward Walsh, of the Police Department of the City of New York, presented an excellent paper on The Commercial-Vehicle Problem in New York City. It had special reference to comparative statistics for 1929 and 1930 with regard to fatal motor-vehicle accidents in Greater New York, caused by careless practices of drivers and pedestrians, collisions of vehicles and the like.

Left turns are a major cause of accidents, said Lieutenant Walsh. He urged the adoption of a policy of co-operation of owner-drivers and commercial-vehicle drivers with the traffic police so that drivers may become educated into considering the subject of accident prevention from the traffic-officers' viewpoint as well as their own. He suggested that drivers obtain police-department instructions and regulations and that they study them carefully.

Selecting and Training Drivers

"Some people ought not to drive a motor-vehicle," said Dr. V. V. Anderson, formerly of R. H. Macy & Co., in beginning the presentation of his paper on the Selection and Training of Motor-Vehicle Drivers. "The remainder ought to be specially trained," he continued. Since recent emphasis has been placed on considering the human factor with regard to the mental and physical make-up of motor-vehicle drivers, he analyzed the results of psychiatrical laboratory-tests made on a group of drivers with the aid of specially designed instruments.

Dr. Anderson urged that better employment technique, better special training and better management be emphasized as major factors constituting safe motor-vehicle operation. He said that the safe operation of a motor-vehicle results from drill in coordinated response to nerve stimulus. An individual may respond, but he may not react in an *appropriate response;* he may know, but he may not respond with quickness and accuracy. This illustrates the necessity for a high degree of constitutional coordination.

Tests were made also in motor-vehicles on the road to determine whether the drivers' actions were quick or slow. The average response was 1.3 sec.; a response of 2.0 sec. was considered poor as regards responsiveness. Other tests were made to determine the correlation between the types of drivers who have accidents and those who do not. Dr. Anderson stated that the driver possessing what may be termed an average intellect is more desirable than one who is more than ordinarily intelligent, because he is more likely to focus his attention on driving and less likely to "dream." In conclusion, the speaker remarked that one cannot "size-up" an applicant for a driver's job, and that the objective method of selecting drivers must be used.

Making Drivers Safety-Conscious

In a paper on this subject G. A. Rogers, a representative of the Hoffman Beverage Co., of Newark, N. J., said that his company's fleet of motor-vehicles operates in the territory extending from Wilmington, Del., to Bridgeport, Conn. About 70 per cent of the company's business is in its so-called New York territory, comprising the five boroughs of New York City and the north and the south shores of Long Island. A through route to Bridgeport from New York City, and another to Peekskill, Poughkeepsie and Newburgh, N. Y., are operated also. The composition of the fleet and its mileage during 1930 are as follows:

Type	No. of Vehicles	1930 Mileage
Trucks		
1-Ton	10	113,411
2½-Ton	42	295,842
5-Ton	92	502,504
Vans	17	299,592
Sanitation Service	8	23,564
Coupés and Sedans	139	1,636,569
Total	308	2,871,482

The trucks are equipped with bodies which, although they have an over-all length of about 28 ft., can operate in the highly congested traffic areas of New York City and Brooklyn. As these trucks average 70 stops per day, a serious parking problem is introduced because of the ever-present risk when pulling into and backing out of parking spaces. Mr. Rogers presented the foregoing fleet-data as a background for his subsequent remarks, and said that the accident problem diminishes or increases according to the size of the fleets and the territory in which the vehicles operate.

Courtesy Is the Company's Watchword

Continuing, the speaker said that the solution of the training problem lies in the selection of drivers, their adequate training and an incentive to keep them constantly alert in their every-day activities. Because undiversified constant training becomes monotonous, stale and unattractive, he advocated that the instruction frequently should revert to fundamental principles. He said further that applicants for driving positions in his organization are subjected to a careful investigation before their applications are passed upon. This includes personal calls on former employers, a careful check-up of past accident-records, and a road test in one of the company's vehicles. This test is so designed and the territory so chosen that it calls for the use of proper hand signals, left and right turns, parking on grades and double clutching.

As soon as a man is employed, Mr.

Rogers continued, he attends the training school for one week at a guaranteed wage sufficient to prevent him from worrying about his income. This enables him to give his best attention to the instruction provided. The speaker then assumed that his audience had been transported to the company's schoolroom and was listening to the instructor's lecture to a group of new drivers, the subject being The Courteous Driver. Constituting himself the lecturer, Mr. Rogers made the following points in the "vernacular."

(1) You men are all licensed drivers and the fact that the State has issued you a driving license should be interpreted by you as somewhat of a compliment. Everyone who applies for a driver's license does not get it. This indicates that your character must be good and that you have no bad record behind you.

(2) You have elected to follow this particular course of employment and you owe it to yourself, your family, your employer and the public to see that you at all times justify this confidence. If you abuse it, the privilege can and will be taken away from you by the revocation of your license.

(3) Government has found it necessary for the protection of us all to enact certain laws and regulations surrounding the driving of a motor-vehicle; although there are certain questionable things that you can do and stay within the law, those things are not necessarily the right things to do.

(4) There is not a man here who would not get up and give his seat to an elderly person in a crowded street-car; there is not one of us but would extend a dozen and one courtesies to a stranger whenever the occasion presented itself. That is one of the reasons why we have selected you to enter our employment. Because you are inherently courteous, we know that you are going to carry that same degree of courtesy to the streets when you take your truck out in the morning; we know also that you are going to extend that same courtesy all day long.

(5) You have *no right-of-way*, if, by yielding it, you can avoid an accident or keep from splashing a pedestrian with water or slush from a puddle. Remember that the average pedestrian or another driver believes that the average truck-driver takes advantage of the weight and size of the vehicle he is driving. We may as well admit that at times in the past we have taken that advantage, but we are not going to do it any longer because it is a closed chapter in our driving career.

(6) Don't be a bully because you drive a big truck. Carry your courtesy into the cab of your truck, when you climb aboard each morning, and just see how much better you feel when you have given some exhibition of it as you go about your daily work.

(7) At an intersection remember that, although you may be the best driver in the city going *into* that constricted area, if you happen to meet the poorest driver in the city you are immediately reduced to his standard of ability, for you cannot tell what he is going to do. It is easier for you to fall to his level than it is for him to reach up to yours. Don't bank too much upon what the other driver is going to do.

(8) If you are EVER in doubt, STOP.

(9) Remember that when you take any vehicle out onto the street with your employers name on it, you lose your identity; you are no longer John Jones; you are your own employer. Everything that you do, good or bad, reflects to the company's credit or discredit.

(10) Someone recently said in a joking way that his idea of a pessimist was the driver that looked both ways on a one-way street. Don't you believe that! If every driver did as he should do, there would be no accidents, but accidents do happen because some driver has not done what he should have done. The records are full of accidents caused, or contributed to, by going east on a west-bound street and west on an east-bound street.

(11) Drive as steadily as possible in one lane of traffic; don't cut in and out.

(12) If a pedestrian becomes confused in front of you, don't add to his confusion by blowing your horn; STOP.

(13) An accident is as dangerous for you as for anyone else; and, while you are being courteous to some person, don't you like to feel that some other driver is being courteous to a member of your family in some other section of the city? There is an excellent chance for applying the Golden Rule in driving.

(14) Drive "kid careful." A youngster is impulsive and, the younger the kids are, the more impulsive they are and the more unlikely things a boy or a girl may do. If you always drive "kid careful," you will be automatically taking care of everyone else.

(15) Road courtesy is one of the surest preventions against accidents. A courteous driver is a safe driver.

Student Meeting Draws Crowd

Detroit Section's New Activity Gets Big Response— S. A. E. Headliners Talk to Young Engineers

NEARLY 500 enthusiastic students and juniors attended the first meeting sponsored by the Detroit Section under its newly organized student activity, which was held on Tuesday, March 3, at 8.00 p. m. in the General Motors Research Auditorium. Various colleges in and near Detroit were represented by groups of students as follows:

University of Detroit	72
Tri-State College, Indiana	20
Detroit City College	14
Detroit Institute of Technology	12
Cass Technical High School, Detroit	74
General Motors Institute of Technology, Flint, Mich.	50
University of Michigan, Ann Arbor, Mich.	3
Michigan State College, Lansing, Mich.	14
Various high schools	8

The rest of the audience was comprised of regular Members, Junior Members and non-members of the Society. The hall was filled to overflowing and many were turned away. A spontaneous response to the speakers was evident throughout the meeting.

Phil Kent, Detroit Section's Chairman, opened the meeting by explaining the purpose of the activity, which, he said, was based upon the principle that the Society is best served by serving well the students and juniors who are automotive-minded. Mr. Kent gave credit to Alex Taub and his committee co-workers, Peter Altman and R. N. Janeway, for the very evident success of the meeting, which he then turned over to Mr. Taub, who urged the need for response on the part of the students and juniors so that interest in the movement will be maintained. He also commented on the fine spirit of cooperation shown by all members of the Society who were connected with the meeting.

Mr. Taub pointed out that the three speakers on the program would be headliners at any regular S.A.E. meeting. They were William B. Stout, president of the Stout Metal Airplane Co.; O. T. Kreusser, research engineer for the Fisher Body Corp.; and A. E. Larsen, chief engineer of the Autogiro Co. of America.

Official color was given the affair by the attendance of T. J. Litle, Jr., W. T. Fishleigh, B. J. Lemon, Professor Altman, Professor Caton, Robert N. Janeway, H. R. Crecelius and J. H. Hunt.

What the Speakers Talked About

Mr. Stout, the first speaker, addressed his remarks to the younger element, giving them much encouragement by pointing out that the engineers of the future must come from their group and that open-mindedness is their strongest asset. "Youth can think in new terms," he said. "Ideas are most important, and ideas and initiative combined make for industry."

Mr. Kreusser, in his talk, touched upon merchandising methods, the psychology of style, and proportion, riding comfort, noise, visibility, entrance and exit, and ventilation in automobiles. He pointed out that all of these important items must be considered in the development of motor-cars. Streamlining is important purely for ventilation and quietness, in his opinion. He said that we have been able to definitely measure speed, fuel and oil economy, brake effectiveness, steering and cold-weather starting. Today, with the development of photo-measurement, style change can also be accurately recorded.

Following his talk, Mr. Kreusser and Mr. Stout engaged in a mild debate at the request of the Chairman regarding

(*Continued on p.* 490)

Chronicle and Comment

Good Business THERE has been the expected falling off in that part of the Society's income which depends directly upon business conditions—our advertising revenue. Good business principles call for an expense adjustment to offset this decrease. Fortunately, a desirable modification is attainable through the curtailment of extras rather than essentials. On this basis, recommendations have been made by a wise Finance Committee and Council.

In line with this policy, publication of the TRANSACTIONS is to be suspended for the period of a year. This action simply means that material already published in the S.A.E. JOURNAL will not be duplicated.

A substantial surplus in the Society's treasury performs its function by allowing us to continue our principal activities with normal vigor during subnormal times. Our committees are administering a full schedule of meetings, our Sections are pushing ahead better than ever, our membership is holding up very well; in fact, all such phases of our work are exceeding average performance.

Prospects for the future are bright!

Motion-Picture Film Available S. A. E. members throughout the Country will now be able to observe the Officers and Councilors of their Society in action, for a recently completed 400-ft. length of 16-mm. film shows these men following their individual pursuits—flying an airplane, driving a fast car on the speedway, inspecting some forgings, just looking natural.

Upon request from the Sections, the home office will schedule the film for prompt showing over as wide an area as possible.

Aeronautic Meeting This Month TIME, APRIL 15 and 16; Place, Book-Cadillac, Detroit—Aeronautical Chamber of Commerce and S.A.E. cooperating.

Superchargers, bearings, lubrication, spark-plugs, aircraft engines, fuel lines, knock rating of aviation gasolines, hull and float construction, textiles, protective coatings, flight testing and a host of other topics will be discussed by practical engineers, leaders in their field.

Read the details on p. 405 of this issue and watch for further announcements. Send your banquet reservations in promptly. It will be a sell-out.

Curtiss Anecdotes GLENN H. CURTISS used to draw his plans and designs on the walls of his shop, then roll up his sleeves and help his men to build machines "that always worked." The contour of an airplane wing was determined by the sweep of Glenn Curtiss' arm rather than by mathematics or wind-tunnel data. The handwriting-on-the-wall method finally suffered a setback when the janitor whitewashed the place, thereby delaying by several weeks the completion of a Navy contract.

Mr. Curtiss was reticent and liked buttermilk. John Towers, who came to work with Mr. Curtiss, was reticent and could not tolerate buttermilk. The ice of bashfulness between the two men was broken and a warm friendship took root when Curtiss induced Towers to drink a glass of the healthful beverage which Towers did not retain long enough to be polite and proper.

Frank H. Russell, of the Aircraft Manufacturers Association, and Capt. John H. Towers, assistant chief of the Bureau of Aeronautics of the Navy, included these items in their very inspiring and interesting eulogies of the great pioneer at the Commemorative Aeronautic Meeting held in February and reported in the March issue of THE JOURNAL.

Useful Oil-Viscosity Charts Available ATTENTION is directed to the item in the Standardization Progress department on p. 486 of this issue under the heading, Valuable Oil Charts Available. The chart illustrated and described has been developed by a member of the Lubricants Division of the Standards Committee of the Society with a view to simplifying the plotting of the viscosities of a lubricant at two temperatures to give a straight-line curve that will indicate its viscosity at any other temperature. The chart is useful alike for engine oils and rear-axle and transmission lubricants.

Milwaukee Spring Production Meeting THE first Production Meeting to be held in the spring, with the cooperation of the National Production Activity Committee, will be at the Hotel Schroeder in Milwaukee on May 7 and 8. Three technical sessions, with two plant visits for demonstrations of the papers, are included in the program, and a Production dinner will be the concluding feature. The meeting is mainly under the auspices of the Milwaukee Section, the National Production Activity Committee having arranged the program for the technical session on the afternoon of the first day. The complete program for the meeting will be found on p. 406 of this issue of THE JOURNAL.

The meeting, while semi-national in character, is being staged mainly for the members in the Great Lakes territory. Plans for the regular National Production Meeting, next October, are in preparation.

Mark These Dates—June 14 to 19! A change has been made in Summer Meeting dates since the March JOURNAL went to press. The many and varied events scheduled for the period of the meeting indicated to the Meetings Committee and to the Council the desirability of beginning activities one day earlier than previously announced; hence the Summer Meeting, to be held at White Sulphur Springs, W. Va., will open on Sunday, June 14, and continue through Friday, June 19.

The scheduling of 15 technical sessions and nearly a score of committee meetings in such a way as to avoid conflict, while yet leaving time available for the various Summer Meeting sports, has necessitated very careful planning, and the Meetings Committee is glad to announce that an arrangement has been formulated that promises to bring about the desired result. Details of this arrangement will be found on p. 406.

Increasing *the* Thrust Horsepower *from* Radial Air-Cooled Engines

By Philip B. Taylor[1]

Annual Meeting Paper

MANUFACTURERS of radial air-cooled engines have centered their attention upon low specific weight for their product. This is accomplished by compact design, using the best of materials and the highest grade of workmanship and finish, with the production of the maximum possible horsepower per cubic inch of engine displacement. High output can be accomplished by a combination of high rotative speed and high brake mean effective pressure with low friction losses. Many considerations of design and operation must be correctly proportioned to approach the ultimate in horsepower.

Important advances have been made in improving engine output by cooling air-cooled cylinders with well designed fins supplied with air from directing baffles, thus increasing the brake mean effective pressure which can be produced on a given fuel without detonation. The complete elimination of all hot spots and a general reduction of temperature in the combustion-chamber at the end of the compression stroke will permit this gain in performance to be carried to even further limits. Other advances in this line are expected through the use of better fuel, mechanical fuel-distribution, compensated valve-gear, higher supercharger-pressure, higher compression-ratio and more efficient superchargers. The standardization and distribution of fuels with a high antiknock rating will make possible substantial increases in output.

Great as are the advances in low specific engine weight, it has recently been found that at least as great an advance in performance of the combined airplane and engine can be accomplished by attention to the aerodynamic characteristics of engines and propellers. The engine manufacturer must apologize for the radial engine in this respect until it is covered with a ring or N. A. C. A. cowl, after which it becomes surprisingly acceptable in drag coefficient.

As engine speeds are increased for the purpose of additional power, reduction gears will become necessary to maintain or improve propeller efficiency.

Discussion of the paper had to do largely with engine noise which, it was agreed, will need to be reduced.

It was stated that availability of improved fuels would make possible an increase of 50 per cent in the output of present aeronautic engines.

ALTHOUGH handicapped by a large frontal area, the radial air-cooled engine has maintained its popularity up to the present. Recent developments indicate that the type is capable of a substantial increase in effective thrust-horsepower, which may help to continue its present advantage. This paper is devoted to a discussion of the present status of the development of radial air-cooled gasoline engines with references to the trend of possible future progress. I believe that this type has a definite place in our present aircraft, but I do not claim that it is superior for all types of service. Whether or not the popular preference for this type will continue must be left to the future.

In this discussion, the engine is held strictly accountable for its own weight and parasitic drag, as the airplane designer could obviously improve the streamlining of his ship and reduce its wing area, thereby increasing its performance, if the engine consisted of a body of neither volume nor mass. The propeller efficiency will also be charged to the engine, as the rotative speed for a given power output is an important factor in this problem. This condition is roughly expressed by values observed in flight for the following formula, where the thrust is measured in pounds and the speed in feet per second:

$$\text{Thrust horsepower} = \text{thrust} \times \text{speed}/550$$

The thrust is measured at the rear of the engine mount and is thus automatically corrected for propeller efficiency, parasitic drag of the engine and interference between propeller and engine.

This formula does not represent the whole problem, because (*a*) no account is taken of the weight of engine unit which has a decided bearing on the design and performance of the airplane and (*b*) the engine frequently determines the size and shape of the fuselage, so that the resistance of this body is partly chargeable to the engine. The formula can therefore be used only to visualize some of the quantities in question.

Since further elaboration of the interdependence of airplane and engine becomes seriously involved and is beyond the purpose of this discussion, it will be assumed that an increase in thrust horsepower is accomplished when (*a*) the engine power is increased at suitable propeller speeds, (*b*) the outside diameter of the engine unit is decreased, (*c*) the operating efficiency of the propeller is increased, (*d*) the drag coefficient of the installed powerplant is decreased or (*e*) the interference between propeller and engine is decreased. Reduction of powerplant weight will also be considered, because of its direct effect on wing area and drag.

The factors governing the horsepower output of an engine are the displacement, the rotative speed and the brake mean effective pressure.

Increase of Displacement Has Practical Limits

Engine displacement is a matter of design which must be determined early during the layout. Roughly, the power output should vary in direct relation to the displacement; but it has been found by bitter experience that, with the same degree of engineering skill, large cylinders will not produce a maximum horsepower proportional in their displacement as compared with small

[1] Chief engineer, Wright Aeronautical Corp., Paterson, N. J.

TABLE 1—OUTPUT PER CYLINDER OF LARGE RADIAL ENGINES

Engine	Bore, In.	Stroke, In.	Displacement, Cu. In.	Speed, R.P.M.	Rated Hp.
Pratt & Whitney, Hornet B	6¼	6¾	206	1,950	64
Bristol, Jupiter F	5¾	7½	195	2,000	58
Wright, Cyclone	6⅛	6⅞	202	1,900	64
Armstrong, Leopard	6	7½	212	1,500	50

cylinders. This is true to such an extent that the opinion has frequently been voiced that air-cooled cylinders of more than 215-cu-in. displacement could not be made to operate satisfactorily at an output which would be desirable for airplane use. Four manufacturers have produced engines having cylinder displacements very close to this figure, as listed in Table 1.

Little reason exists to believe that the limit of engine development in any direction has yet been reached, but I believe that engineers will agree that larger cylinders are more difficult to develop and that their horsepower output is disappointing. Valve sizes required and the increased distance for heat to travel from the center of the piston to the cylinder-walls contribute to the limitations of large air-cooled cylinders.

It is, therefore, advantageous to increase displacements by using a large number of small cylinders rather than by attempting the development of a small number of large cylinders. This has the added advantage in a radial engine of producing a unit of which the torque curve is smoother and the secondary unbalance less pronounced. The single-row radial engines have generally been limited to 9 cylinders, although at least one 11-cylinder engine has been built. The 9-cylinder limitation comes from a consideration of engine diameter, as 9 cylinders of ordinary proportions will just fit around the circle necessary to clear the path of the head of the master connecting-rod. A larger number of cylinders necessitates an increase in crankcase diameter and at the same time reduces the section of crankcase material between cylinder-barrels, affecting the strength of the crankcase.

Two-bank radial engines present an added opportunity for large displacement with small cylinders. Fourteen has so far been considered the maximum number of cylinders for this construction, as substantial spaces are required between the front cylinders to cool the rear cylinder. Armstrong Siddeley Motors has developed a line of engines of this arrangement. The largest of these, shown in Fig. 1, has a displacement of 2969 cu. in. and is rated at 700 hp. at 1500 r.p.m. Other 14-cylinder, two-row radial engines are in the process of development in this Country but have not yet been put on the market. This type is considered attractive for large sizes and will be compared with the single-row engine in this paper.

Within the last two years both the Pratt & Whitney and the Wright companies have increased the displacement of their large 9-cylinder engines in an effort to obtain additional horsepower. The engine characteristics given in Table 2 show the results obtained.

TABLE 2—CHARACTERISTICS OF TWO ENGINES BEFORE AND AFTER AN INCREASE IN SIZE

	Displacement, Cu. In.	Bore, In.	Stroke, In.	Diameter, In.	Speed, R.P.M.	Rated Hp.	Rated Brake Mean Effective Pressure, Lb. per Sq. In.
Hornet	1,690	6⅛	6⅜	55 7/16	1,900	525	130
Hornet B	1,860	6¼	6¾	56 3/4	1,950	575	126
Cyclone	1,750	6	6⅞	54 11/16	1,900	525	125
Cyclone, Large	1,820	6⅛	6⅞	54 11/16	1,900	575	132

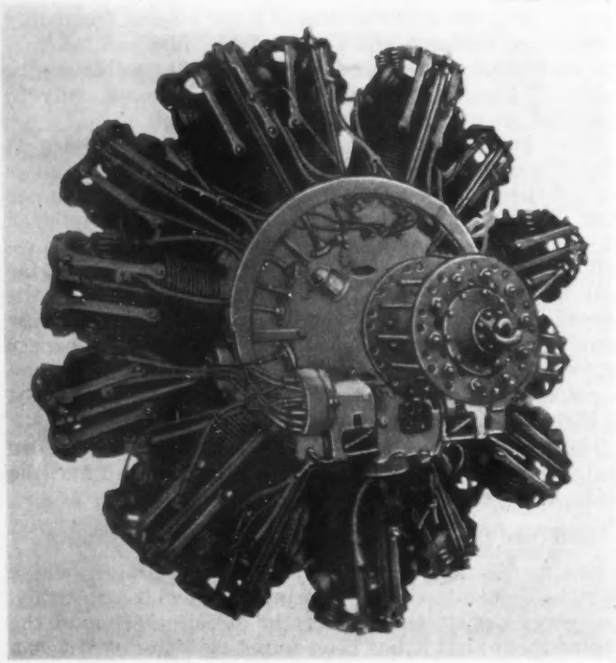


FIG. 1—ARMSTRONG SIDDELEY LEOPARD ENGINE

The 14 Radial Air-Cooled Cylinders Are Arranged in Two Rows and Provide a Total Piston-Displacement of 2969 Cu. In.

It should be noted that, while the increased displacement of the Hornet B would presage 52 hp. additional, at the same speed as the smaller Hornet, it was necessary to add 50 r.p.m. to the speed to obtain a rating of 50 hp. additional. A slight sacrifice in engine diameter also was necessary. This illustrates the disproportionate gain in power of large cylinders from an increase in displacement.

An increase of 23 hp. might have been expected from the Cyclone, on the basis of displacement, but this was not actually attained until additional supercharger pressure was provided to produce the desired power at the same crankshaft speed. This increase in power could have been obtained by the use of still higher supercharger-pressure on the 1750-cu-in. Cyclone engine without the change in displacement. The same may also be true of the Hornet engine. In any case, the troubles incident to large cylinders were experienced on both engines and considerably more development work was required than was originally anticipated, and I believe that small gains in displacement by the redesign of existing large-cylinder types are of doubtful value.

Valves and Passages Limit Rotative Speed

Increasing the rotative speed of an engine having rotary induction or supercharging is one of the most attractive means of increasing the power output, but it has the serious disadvantage of decreasing the propeller efficiency if the tip speed goes beyond certain limits. This can be overcome by the use of reduction gears, at a sacrifice in weight of the powerplant unit. For the

moment we will consider the limitations in engine speed without reference to other effects.

Unsupercharged engines will peak in brake mean effective pressure when an intake-gas velocity of approximately 160 ft. per sec. is attained. The horsepower output will peak at a slightly higher speed, forming a definite limit to rotative speed in this type. Some increase in speed may be obtained by a review of design, including the enlargement of valves and valve passages; but this procedure is soon limited by the space available in the combustion-chamber and by rough running at low speeds because of too much wetted surface in the induction system and of choke areas in the carbureter becoming too large to produce sufficient jet suction.

The push-rod valve-gear of most radial air-cooled engines sets one of the serious speed limitations. This is especially true with large cylinders having two valves, in which the exhaust valve alone may weigh almost 1 lb. This mass, together with that of the springs, washers, rocker-arms, push-rod tappets and rollers must be accelerated and decelerated in such a short time that the forces on the valve gear become enormous. This is especially true of uncompensated valve-gears such as are popular in this Country. Cams for such gears must be designed so that the pick-up velocity for valve clearances from 0 to 0.090 in. is 2 ft. per sec. or less and the seating velocity is approximately the same, to prevent failure of valve gear and valves. This requirement cuts down the time available to get the valve open and closed, necessitating heavy valve-springs to keep the valve gear from jumping the cam as it is decelerated over the top of the lobe.

Several improvements can be made in present valve-gear to increase its operative speed. The valve gear can be compensated for temperature effect, either by a hydraulic means of taking up the clearance or mechanically by pivoting the rocker-box at the centerline of the valve. The latter method requires a separate rocker-box, and considerable ingenuity must be exercised to secure the grease-tightness which is desirable. Clearance compensation allows the use of a cam on which the clearance ramp is greatly reduced. More time is then available in which to accelerate and decelerate the valve, thereby reducing the necessary spring-load and the initial impact, which is the destructive portion of the valve lift.

Successful efforts to reduce the mass of the valve and valve gear without decreasing its strength will be rewarded by increased operative speed with the same degree of reliability. The L-head cylinder, with valves operated by straight-line motion from a cam, is one attractive design which accomplishes this purpose. An F-head can also be used, with the lighter and cooler inlet valve on top. Several small L-head engines are already on the market. The MacClatchie Panther, shown in Fig. 2, illustrates this type, which should reduce the valve-gear limitations for high-speed operation. The use of a natural induction system, however, limits the engine speed by a sharp drop in volumetric efficiency. The more extensive use of L and F-heads is expected within the next few years, because of their simple, light valve-gear and for other reasons.

The stress imposed on moving parts is another limitation to speed. This is entirely a matter of design and can be overcome within limits at a sacrifice of weight and possibly engine diameter. A short-stroke engine of large bore has a great advantage in this respect, as the velocities and accelerations of moving parts are lower. While the mass of pistons is increased because of their larger diameter, this effect is more than balanced by the lower velocities and the smaller mass of a shorter connecting-rod. The stroke cannot be shortened much beyond 80 per cent of the bore, as the lower ends of the cylinders then begin to interfere at a distance from the center of the engine that is sufficient to allow clearance for connecting-rods, and further shortening of stroke and increasing of bore will result in a badly proportioned crankcase. Cooling of the center of the piston-head is difficult in large cylinders and may limit the bore-stroke ratio. The principal advantage of a short-stroke large-bore engine is the space available for large valves.

Bearing loads and velocities have increased steadily on radial engines and will probably continue to do so as speeds and outputs are increased. The conclusion of A. G. M. Michel and Albert Kingsbury that the greater the relative speed the greater the load which can be carried on a plain bearing, with oil-film lubrication, is being put into practice. Roller and ball-bearings, while loaded to several times their original rating, continue to be satisfactory for long periods of service and give evidence of withstanding further abuse. Bearings, therefore, do not at present limit the rotative speeds of engine crankshafts.

How Sticking of Pistons Is Prevented

The piston bearing on the cylinder-wall has been a critical factor in high-speed, high-output engines. A bearing of aluminum against moderately soft steel—subjected to heat from the combustion-chamber, obtaining limited lubrication for purposes of oil-consumption control and subject to cylinder and piston deflection—presents a difficult problem. Many steps have been taken to improve the reliability of pistons and many theories advanced to explain why they stick. The

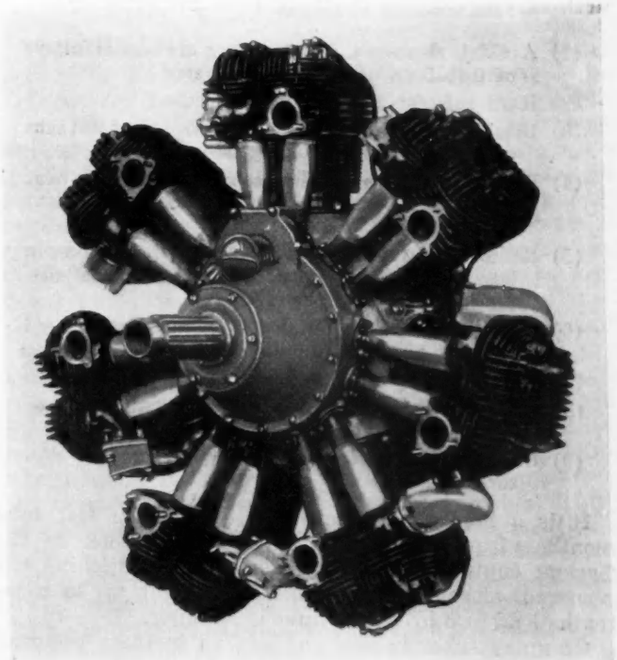


FIG. 2—MACCLATCHIE PANTHER ENGINE

The Seven Radial Cylinders Provide a Piston Displacement of 612 Cu. In. L-Head Construction Makes Possible Direct Operation of the Valves and Holds the Over-All Diameter to 36 In.

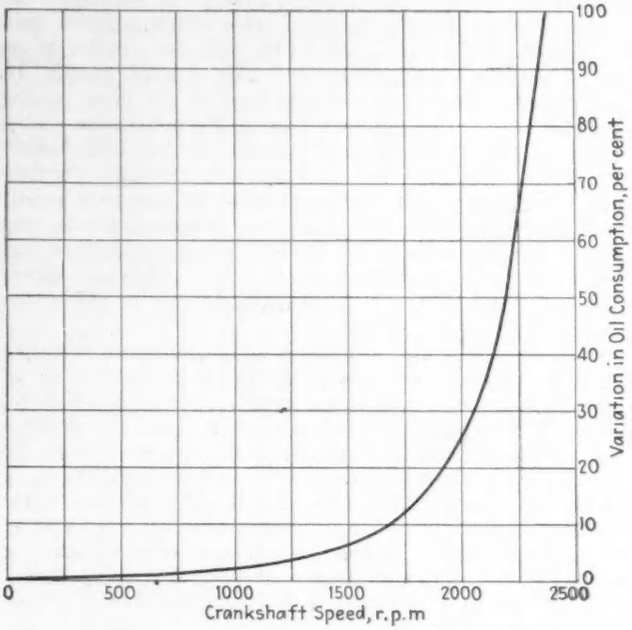


FIG. 3—TYPICAL OIL-CONSUMPTION CURVE OF RADIAL ENGINE

greater problem is to explain why they work; but the fact remains that they do, if properly designed and given suitable clearance and lubrication. Large cylinders are more susceptible to piston sticking than small cylinders, as their operating conditions are obviously more severe. The so-called antithrust side of the master-rod piston in conventional design is subjected to the highest mean wall-pressure and is usually the first to give trouble. The following measures have been used with varying success to eliminate piston sticking:

(1) A skirt clearance for ordinary aluminum alloys of 0.0045 in. per inch of diameter
(2) Hard cylinder-barrels
(3) Dissipation of as much heat as possible from ribs on the under side of the piston
(4) Providing the shortest possible path for heat from the center of the piston to the piston skirt and rings
(5) Relieving the sides of the piston at the piston-pin bosses to prevent hard contact because of distortion
(6) Lubricating the piston skirt by suitably arranged rings or an oil jet against the cylinder-walls
(7) Long initial running at low output
(8) Low piston-side-pressures resulting from the use of relatively long connecting-rods
(9) Uniform cylinder-barrel cooling to prevent distortion

It is a noteworthy fact that, during the last four months of production and experimental work on the Cyclone engine, not a single case of piston sticking has occurred, although the engine is brought up to nine-tenths load in 3 hr. of continuous running.

On many supercharged engines, an increase in speed will not be accompanied by a corresponding increase in horsepower because of a drop in brake mean effective pressure. This occurs in spite of the fact that, for a given supercharger design and gear ratio, the inlet-manifold pressure will increase with the engine speed under full-throttle conditions, since the pressure from the supercharger increases as the square of its speed while the requirements of the engine increase directly as the speed. The results of this will be mentioned in my later discussion of brake mean effective pressure.

Torsional vibration of the crankshaft must be watched carefully as the engine speed is increased. This subject has received a great deal of attention during the last year and was discussed at length by Floyd Prescott, of the powerplant laboratory, Materiel Division, Air Corps, in a recent paper.[2] One suggestion that Mr. Prescott did not make concerns the possibility of the use of a torsional-vibration damper, similar to those used so extensively and successfully on automobiles, on aircraft engines. The use of such a device has the advantage of reducing to a safe amplitude torsional vibration at all speeds, even though the engine is subjected to dive maneuvers in which the final engine-speed may be 50 per cent greater than that for which the engine is rated.

Variation of oil consumption with engine speed is another problem which may limit the speed of a radial engine unless it is given careful attention. The curve in Fig. 3 illustrates the rapid rise of consumption after a certain speed is reached. The point at which this rise occurs can be varied by changes in piston-rings and pistons, but the general shape of the curve has been surprisingly constant in my experience. Many varieties of oil-control ring have been used by various manufacturers in attempts to control oil consumption. The best

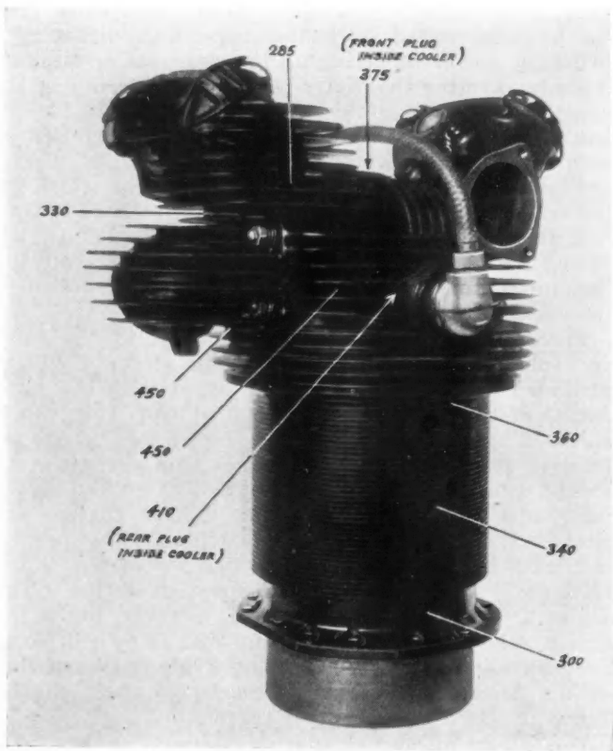


FIG. 4—CYLINDER OF LATEST CYCLONE ENGINE

New Spark-Plug Cooler, with Radio-Shielded Cap, Is a Prominent Feature. Figures Surrounding the View Indicate the Temperatures at Various Points under Full-Throttle Operating-Conditions on a Test Stand

[2] See *Transactions of the American Society of Mechanical Engineers*, May, 1930, Paper AER 52-19, p. 139.

means in the experience of the Wright Company is the old-fashioned bevel-face ring with plenty of oil-drain holes through the piston. The use of compression rings having a 1-deg. taper on the face, with the greatest diameter toward the bottom, assures quick wearing-in of rings and prevents high oil-consumption during the early stages of running. An increase in oil consumption after the bevel is worn away is prevented by the then accurate seating of the rings.

Cooling the cylinder-head and piston is the problem that will, in many cases, limit the speed at which an engine will operate satisfactorily. Since this same problem directly affects the cylinder output, it will be discussed later in that connection.

Detonation Limits Mean Effective Pressure

Brake mean effective pressure is the measure of cylinder output without reference to engine speed. The torque and brake mean effective pressure for a given engine are proportional. The brake mean effective

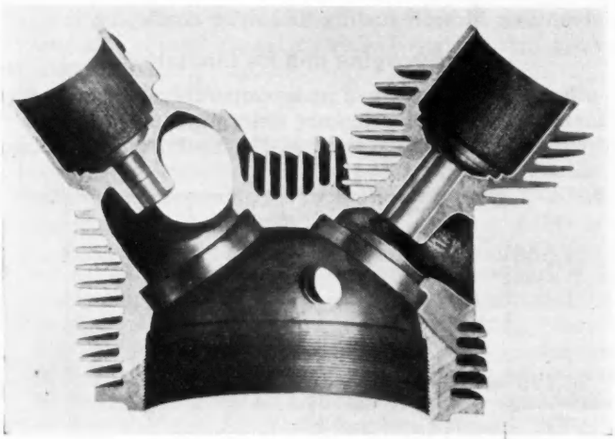


FIG. 5—SECTIONED HEAD OF CYCLONE CYLINDER

The Number and Proximity of the Cooling Fins near the Exhaust-Valve Seat and Guide Aid in Reducing the Temperature of the Sodium-Cooled Valve

pressure of an unsupercharged engine usually is limited by the volumetric efficiency obtained under the restrictions of the induction system. The induction system is frequently so restricted to permit full-throttle operation under relatively high compression-ratios with little attention to fuel characteristics or cylinder cooling. This is especially true when the fuel consumption is set rich at full throttle to assist cylinder cooling. With the introduction of rotary induction and supercharging, the induction system is no longer the limiting factor, and the power of the engine can be boosted until some other trouble is encountered. That trouble usually is detonation which, if allowed to continue, will destroy the stoutest engine. I will not attempt to define detonation but will confine myself to methods of avoiding it.

A few items intimately connected with detonation are

(1) Combustion-chamber shape and position of valves and spark-plugs
(2) Cooling of combustion-chamber and exhaust valves
(3) Compression temperature and pressure
(4) Fuel consumption
(5) Spark-advance

[8] See S.A.E. JOURNAL, October, 1930, p. 413.

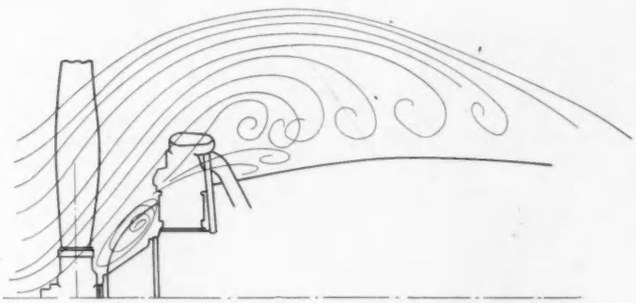


FIG. 6—SKETCH SHOWING PROBABLE AIR-FLOW OVER AN UNCOWLED ENGINE IN FLIGHT

(6) Atmospheric conditions, especially the amount of moisture present
(7) Detonating qualities of the fuel, as measured by the octane rating

Very little work has been done on the effect of combustion-chamber shape on radial air-cooled engines. Flat-head combustion-chambers were used on early models because they avoided valve angularity and side thrust on the rocker-arm mechanism. The later trend has been toward hemispherical heads, because this form makes room for larger valves and resists warping under explosion pressure. No thought has been given to combustion conditions, because the hemispherical head with spark-plugs located on opposite sides of the combustion-chamber has been very successful. Undoubtedly the work of H. R. Ricardo, R. N. Janeway, W. A. Whatmough and Alex Taub[8] could be utilized to advantage by radial-engine manufacturers. This development may well take the form of an L-head engine, which will also have the advantage of the simple valve-gear as previously mentioned.

Extra Cooling Reduces Detonation

The detonating qualities of a cylinder are affected greatly by its cooling characteristics. In designing a cylinder for maximum cooling, it is first essential to obtain the maximum practicable fin area. This must be done in such a way as to allow the cooling-air to flow to all parts of the cylinder fins with the minimum obstruction. Special attention should be given to the critical spots on the cylinder which tend to operate at higher temperatures. These are the two spark-plugs, the exhaust valve and the portion of cylinder between the exhaust port and the rear spark-plug. Fig. 4 shows a spark-plug cooler developed by the Wright Company and used on several models. This device provides a ready outlet for heat which is generated at the spark-plug, especially if air circulation is induced over its fins. Any type of spark-plug can be used with the cooler, which lends itself to complete radio shielding. The effect of the cooler is to reduce the temperature of the rear spark-plug boss and the metal in this vicinity by approximately 125 deg. fahr. when air circulation is induced. The maximum temperatures recorded at the rear spark-plug boss on a new Cyclone engine under the worst conditions are in the neighborhood of 450 deg. fahr., as opposed to 575 deg. on the old Cyclone.

A corresponding temperature-reduction has been accomplished on other parts of the cylinder-head by the addition of 50 per cent more fin area. The valve-guide boss and valve seat, since they are the only effective means of cooling the exhaust valve, should receive spe-

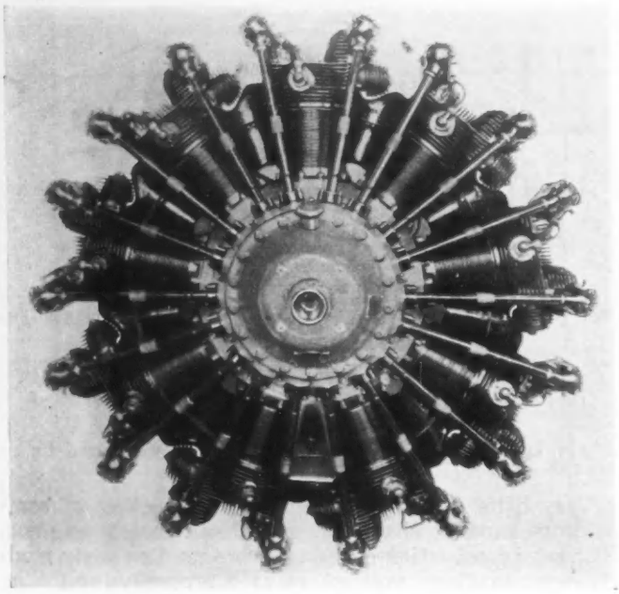


FIG. 7—FRONT VIEW OF WRIGHT CYCLONE ENGINE
Baffles between the Cylinders Direct the Air around the Rear of the Cylinder-Barrels and the Rear Spark-Plug Coolers

cial attention with regard to fin area and air-flow. Fig. 5 shows a section through a Cyclone exhaust-valve-guide boss, bringing out the proximity of the cooling fins to this part to which the heat of the sodium-cooled valve is transferred and where it is dissipated. This, together with a multiplicity of fins behind the valve seat, is a leading factor in the improved Cyclone performance. The top of the cylinder-head is also an important place to cool and should be arranged with fins having the shortest possible heat path from the dome of the cylinder.

Cowls and Baffles Cut Resistance and Help Cooling

In designing cylinder fins it is too often assumed that the air is flowing straight at the engine. Fig. 6 shows the approximate air-flow as indicated by streamers on a test of an uncowled engine. This diagram shows that nearly all the air escapes the engine and flares out at a steep angle to a large diameter, causing high head-resistance. Cooling-air displays a surprising amount of stupidity in not knowing how to find the rear of a cylinder. A cylinder of a former type of Cyclone engine has been measured for roundness under operating conditions and found to be 0.012 in. out of round due to uneven cooling. This led to the development of cylinder baffles to conduct the air to the rear of the cylinder, as shown in Fig. 7, minimizing the out-of-round condition by even heat dissipation.

Cyclone engines are arranged with baffles which induce an air-flow over the back of the cylinder-barrels and deliver a blast of air to the rear spark-plug cooler. While the temperature at the cylinder-flange is not greatly affected by this means, the finned portion is more uniformly cooled. The temperature of the rear spark-plug cooler is reduced about 50 deg. fahr. by air from the baffle, as the temperature is about 400 deg. with the baffle and 450 deg. without it under severe test-conditions. The temperature distribution over the Cyclone R-1820E cylinder under such conditions is indicated by the numerals around Fig. 4. While the test conditions are severe, no temperature on the cylinder-head is above 450 deg., which is a decided improvement over former Wright engines in which cylinder-head temperatures of 575 deg. were not uncommon.

The strength at various temperatures of the Y-alloy, of which the cylinder-head and piston are made, is shown in Fig. 8, indicating an increase in strength of about 75 per cent from lower head-temperature.

The ring cowl and N.A.C.A. cowl have been considered by many as a serious hindrance to cylinder cooling. This resulted from early experiments which were not altogether successful because the full nature of the problem was not understood. Much remains to be learned, but we have found it possible to improve cooling with such a cowl if it is properly designed. Fig. 9, showing the probable air-flow over an engine with ring cowl, illustrates the straightening action on the air, which is forced to pass closely over the cylinders instead of going far beyond them as shown in Fig. 6. The use of a ring cowl as standard equipment on all engines would be most advantageous, because it gives a decided advantage in both cooling and drag coefficient.

Supercharging and Its Limitations

Compression pressure and temperature in an engine having natural induction are determined by the restrictions of the induction system, the heat transfer during

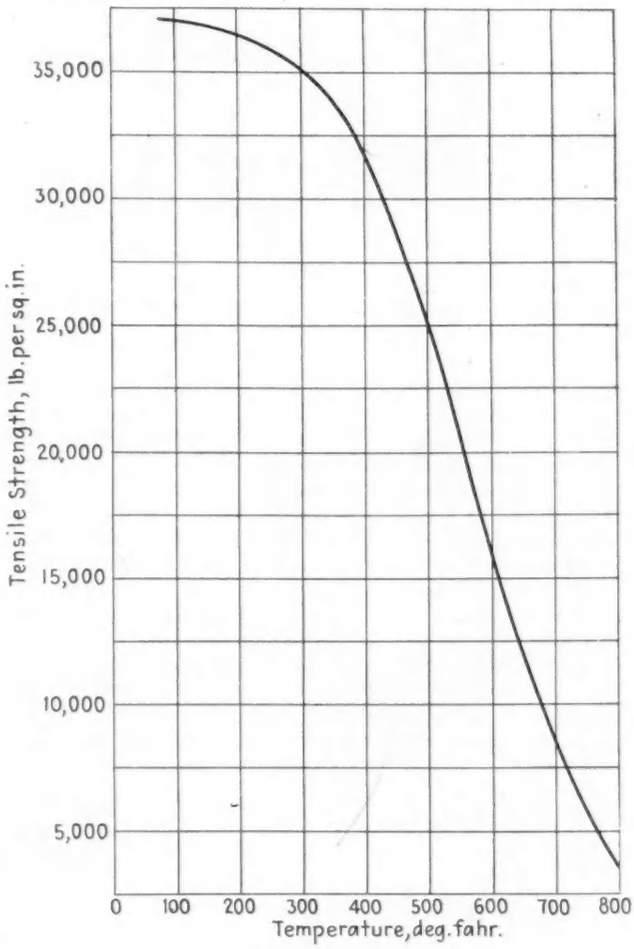


FIG. 8—TENSILE STRENGTH OF Y-ALLOY ALUMINUM AT ELEVATED TEMPERATURES

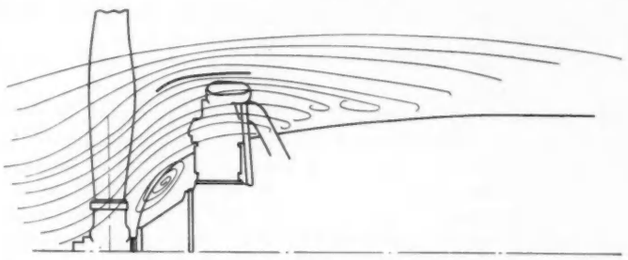


FIG. 9—SKETCH SHOWING PROBABLE AIR-FLOW, IN FLIGHT, OVER AN ENGINE EQUIPPED WITH A RING COWL

induction and compression, and the compression ratio. Restrictions of the induction system have the obvious effect of reducing the cylinder pressure at inlet-valve closing, and thus the volumetric efficiency. Results of this effect have already been discussed. The heat transfer during induction and compression will vary with the running temperature of the cylinder and induction system. This effect is probably not far from constant in most radial air-cooled engines that have not rotary induction.

The desirability of using high compression-ratio has been known for many years. Fig. 10 indicates that higher compression is accompanied by both increased power and lower specific fuel-consumption. The limitation of compression ratio is the antiknock qualities of the fuel used, which will be discussed later in this paper.

The pressure at the point of inlet-valve closing can be varied on an engine equipped with a supercharger, with a resulting direct effect on power output and knock tendency. Assuming an engine in which all other conditions remain constant below the point of detonation of the fuel, an increase in supercharger pressure should be accompanied by an increase in power approximately in direct proportion to the absolute pressure in the inlet manifold. If this process is carried to the point of detonation, a sharp reduction of power will result. Supercharging can be carried to a point just short of detonation without the necessity for high-specific-fuel settings to control head temperatures in a well-cooled cylinder. As previously stated, some engines will not respond to supercharging in proportion to the inlet-manifold pressure, even below the point of detonation. The decided improvement obtained by increasing the area and cooling qualities of exhaust valves on engines with this characteristic leads to the opinion that this limitation is caused in part by a restricted or a hot exhaust valve.

The effect on engine performance of changing both the compression ratio and the manifold pressure is interesting. Fig. 11 shows curves obtained from a single water-cooled cylinder with all conditions excepting the compression ratio, manifold pressure and fuel consumption held constant. The compression ratio was varied by uniform increments, the manifold pressure was increased to the point of incipient detonation in each case, and the fuel consumption was adjusted for a reduction of 1 per cent from maximum power. The results show a gain in power and an increase in specific fuel-consumption for the lower compression-ratios and higher manifold-pressures. A gain in power within limits can thus be made with a given fuel, at the expense of a loss in fuel economy, by reducing the compression ratio in the cylinder and increasing the compression done in the blower.

Fuel consumption has a marked influence on cylinder temperature and knock tendency. This can best be illustrated by Fig. 12, which shows both engine power and cylinder temperature plotted against specific fuel-consumption. The values vary for different engines, but the effect is similar. It will be noted in general that the higher the antiknock rating of a given fuel, the lower the specific fuel-consumption on which the engine will operate and pull approximately maximum power. This is true until no detonation whatever is present, in which case all suitable gasoline fuels will give approximately the same results, discounting distribution losses.

The output of an engine operating with a carbureter may be limited by the temperature of the leanest cylinder. This becomes a serious handicap in the case of poor distribution, as the mixture can be too lean in the leanest cylinder while it is still too rich in the richest cylinder. Rotary induction assists distribution throughout the operating range of throttle position, but it is far from a complete solution of the problem. Variable-capacity fuel-injection pumps, which are under development, discharge an equal quantity of fuel into each cylinder or the corresponding inlet pipe and completely solve the distribution problem. A Diesel-engine pump can be used for this purpose; but the discharge is at low pressure, as the fuel is delivered during the intake stroke. The pump for a conventional Otto-cycle engine is therefore a simpler problem than that for a Diesel engine. This fact has led to the development of several types for this special service. The fuel charger, as the pump is commonly designated, improves other conditions as well as distribution. No heat is required in the manifold to aid distribution by vaporization, as the pump mechanically discharges an equal quantity of fuel

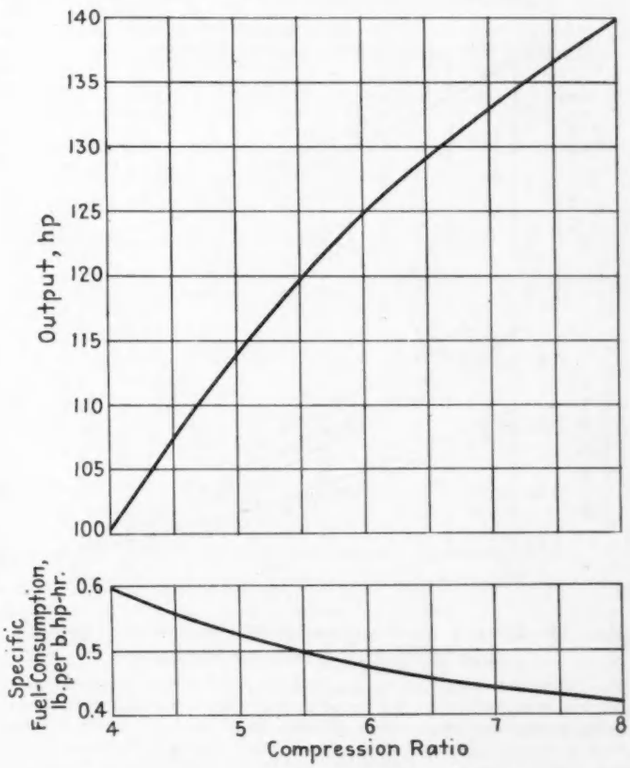


FIG. 10—EFFECT OF COMPRESSION RATIO ON POWER AND FUEL CONSUMPTION AT CONSTANT SPEED

to each cylinder. The volumetric efficiency is therefore increased because of the lower temperature during compression. The spray nozzle produces imperfect atomization and only a small amount of vaporization takes place before the charge is ignited, which has a tendency to suppress detonation. The result of the foregoing effects permits operation without detonation on a given fuel at approximately 10-per-cent-greater output with the fuel charger than with the carbureter. This higher output can be obtained at a somewhat lower specific fuel-consumption. Engines equipped with fuel chargers are not yet on the market, but they may be expected within the next year.

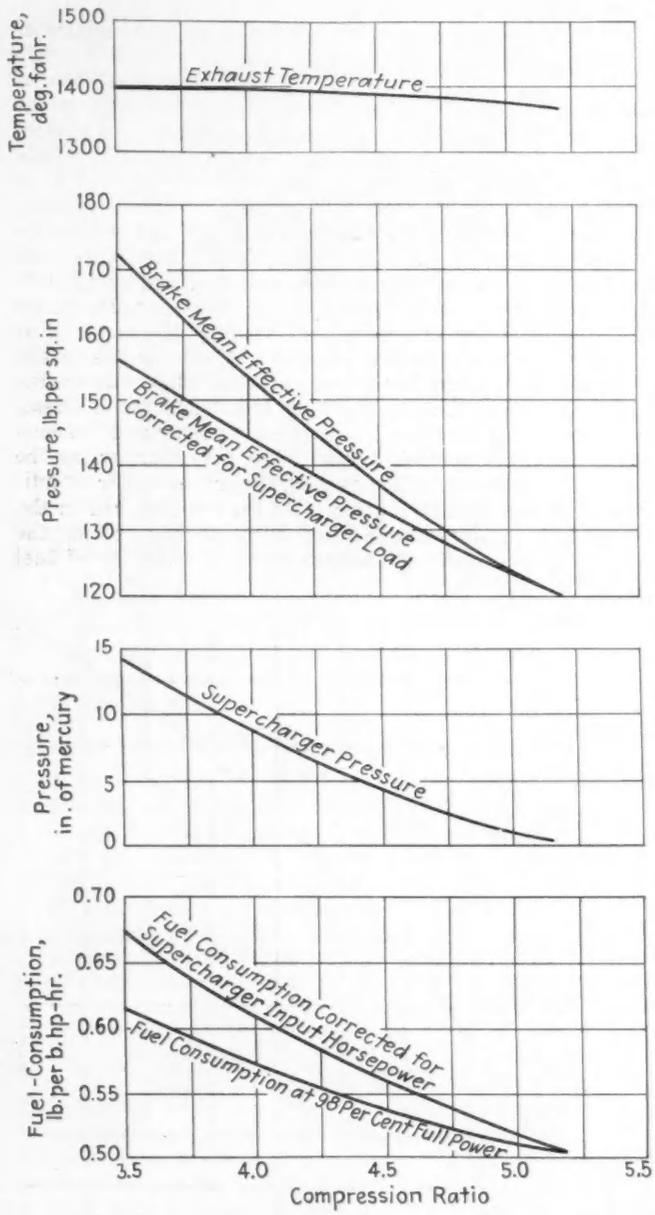


FIG. 11—EFFECT OF SIMULTANEOUS CHANGE OF COMPRESSION RATIO AND MANIFOLD PRESSURE

The Manifold Pressure in an N.A.C.A. Universal Experimental Engine Was Raised to the Point of Incipient Detonation for Each Compression Pressure. The Engine Was Run at 1510 R.P.M. with a Spark-Advance of 35 Deg., Inlet Air at 150 Deg. Fahr. and Outlet Water at 180 Deg. Fahr. The Barometer Stood at 760.9 Mm. (29.96 In.) and the Fuel Was Domestic Aviation Gasoline Having a Specific Gravity of 0.71. The Supercharging Efficiency Was Assumed To Be 60 Per Cent

The perfection of a fuel charger to provide mechanical distribution of fuel in or near the cylinder makes possible the development of a two-cycle engine with cylinder scavenging provided by a centrifugal or Roots-type supercharger. This can be applied to the radial air-cooled engine of conventional type by suitable modifications, opening a completely new field for increasing engine output and thus thrust horsepower.

Spark-advance is another factor which must be taken into consideration in discussing detonation and engine power. The optimum condition is determined by experiment, but most engines are not sensitive to it. Spark-advance should always be specified as the least advance which will produce maximum power under the operating conditions for which the engine is designed. The cylinder temperatures will be somewhat lower with this setting than with a greater spark-advance.

Although its influence is not usually recognized, the presence of moisture has a great effect on detonation. Engines will frequently perform perfectly without detonation on one day and refuse to pull maximum power on the next under otherwise similar conditions, simply from the effect of humidity. Water is an excellent fuel dope and has a noticeable effect even when in atmospheric suspension. Unfortunately, water cannot be mixed with gasoline to suppress detonation. Atmospheric humidity should be considered when testing an engine to determine knock characteristics.

Octane Percentage Grades Fuel Best

Intensive research on the detonation properties of fuel has brought out a wide difference in antiknock values of fuels commonly known as domestic aviation gasoline. Numerous scales by which this value can be measured have been devised, one of which stands out as giving more consistent results than the others. The antiknock characteristic has nothing to do with volatility, and what is called high-test gasoline may be an inferior product in the all-important characteristic of detonation. The most satisfactory and generally accepted measure of detonation is expressed in terms of the percentages of a mixture of heptane and iso-octane to which the fuel is equivalent in detonating characteristics. This scale is gaining in popularity, and it is hoped that it will be adopted as an S.A.E. Standard. The determination of antiknock values is a delicate operation in which measurements are taken on a single-cylinder engine with all conditions controlled—including the jacket temperature, which must approximate that of the type of engine for which the fuel is intended. A jacket temperature of 300 deg. fahr. is now used in testing air-cooled and Prestone-cooled engines. The fuel-calibrating process should not be confused with the calibration of engines in terms of fuel requirements for various compression-ratios or supercharger-pressures. The following antiknock values may give a general idea of relative positions on the iso-octane-heptane scale:

	Iso-Octane	Heptane
Army Standard for 1931	87	13
Army Standard for 1930	80	20
Best California	75	25
Average Domestic Aviation Gasoline	66	34
Poorest Domestic Aviation Gasoline	53	47

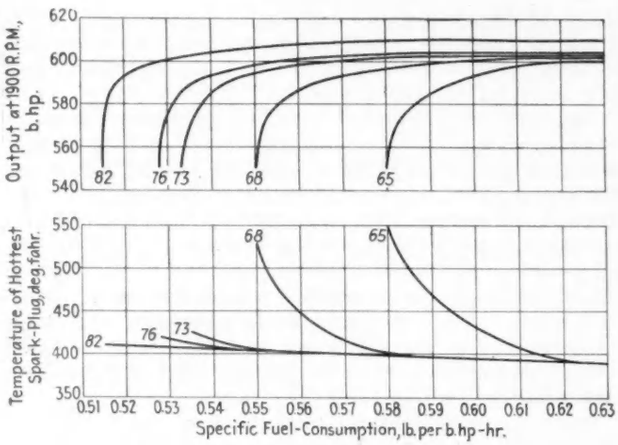


FIG. 12—VARIATION OF POWER AND CYLINDER-HEAD TEMPERATURE WITH FUEL CONSUMPTION

These Curves Were Obtained from a Cyclone Engine Using Fuels of the Different Iso-Octane-Heptane Ratings Indicated by the Octane Figures on the Curves

In preparing engines for service, whether military or commercial, a decision must be made concerning the antiknock characteristics of the fuel to be used. Whether this determination is made consciously or unconsciously, it is reflected in the power output of the engine. Most aircraft engines with natural induction will operate on domestic aviation gasoline with a knock rating as low as 66 iso-octane, 34 heptane, especially if the fuel consumption is high at full throttle. This rating represents an ordinary Mid-Continent fuel. As already shown, many fuels are rated below this figure and will therefore give trouble at full throttle even in engines without ground boosting.

Engines with rotary blowers can be adjusted by the blower gear-ratio and compression ratio to obtain the maximum horsepower which the cylinder cooling and other characteristics will permit when using a given fuel at a given fuel-consumption. To avoid service troubles from detonation, it is essential for the engine manufacturer to select and specify as minimum the fuel of lowest knock rating on which the engine is to be operated under the worst atmospheric conditions and to determine a compression ratio and supercharger pressure at full throttle for the development of maximum safe power output. This has seldom been done in the past, and zones of service trouble have existed where fuel of low antiknock value is sold.

A tremendous advantage in maximum thrust-horsepower can be obtained in an engine of radial or any other type by the use of high-antiknock fuel. This is illustrated by Fig. 13, which shows the maximum brake mean effective pressure before detonation plotted against the iso-octane-heptane ratings of the fuels. This curve was determined on one particular engine, but it shows roughly the general trend for all engines.

The horsepower output of any engine using any given fuel depends on the variables which have already been discussed. A gain in output will always be possible, however, when the detonating qualities of the fuel are improved. For this reason it is essential to the progress of the aircraft industry that fuels which are maintained at a high standard iso-octane rating be put on the market and given wide distribution. A movement to accomplish this is already under way, to which the engine manufacturers in general lend their hearty support, as it will permit them to specify a definite fuel and base their engine guarantees on its use.

Friction Losses Greatest at the Piston

Obviously, a reduction in friction loss with no compensating effect on indicated power will increase the brake horsepower of an engine. The mechanical friction of an air-cooled radial engine is usually about 15 per cent of the power output. Since a great part of this is piston-skirt and piston-ring friction, the use of slipper pistons with reduced wall-surface and fewer rings will reduce the total engine friction to some extent. The difficulty of controlling the oil consumption with slipper pistons has prevented their use in this Country, although they are almost universally used in Europe. Other methods of reducing mechanical friction are disappointing in their almost negligible effect.

Neglecting explosion effects, the power required to drive a supercharger or rotary blower is partially recovered in the combustion-chamber, because the pressure developed in the manifold system is transformed into work on the piston-heads during the suction stroke. A correction must be made for the efficiency of the blower, which is usually from 50 to 70 per cent, and a similar correction for losses in the manifold system and at the inlet valves. The percentage of energy which is not useful for compression adds to the temperature of the mixture, which is further raised by the adiabatic compression. The high temperature of the incoming charge resulting from supercharging has a decided effect on the volumetric efficiency and the knock tendency of the engine. A gain in supercharger efficiency therefore reduces the power loss in the supercharger which, in turn, cuts down the tendency toward detonation by reducing the temperature of the compressed charge at the point of ignition.

Supercharger design is subject to partial mathemati-

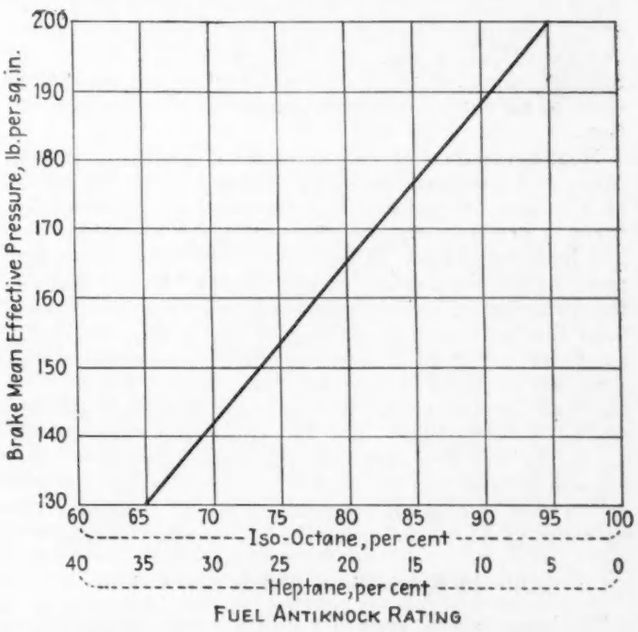


FIG. 13—RELATION BETWEEN ISO-OCTANE-HEPTANE RATING AND MAXIMUM MEAN EFFECTIVE PRESSURE

This Curve Shows the Maximum Brake Mean Effective Pressures That Can Be Obtained from a Well-Designed Cylinder While Using Fuels of Various Knock Characteristics

cal analysis, but it contains many elements of an empirical nature. It is believed that further experiments on superchargers in conjunction with engines will be advantageous in decreasing power loss and thus increasing engine thrust-horsepower. Obviously, the supercharger must make up for wire-drawing in the induction system from the carbureter through the inlet valve. Large, smooth passages will therefore decrease the work to be done by the supercharger. Small size of inlet valves is one of the commonest causes of serious restriction.

Engine Drag-Coefficient Not Proportional to Diameter

The engine designer must appreciate that he is supplying a powerplant which becomes an integral part of an airplane and determines its characteristics to a great extent. In this connection, the weight, size and head-resistance in flight must receive scrupulous attention. The effect of powerplant weight has long been appreciated by the engine manufacturer, since weight per horsepower is the basis of engine sales.

Careful design is, of course, the best method of keeping weight to the minimum. In general, a light engine is produced by designing initially for minimum weight at the expense of strength and then increasing sections as failures occur. This procedure is expensive and involves delay, although it is always easier to add weight than to take it off. Further progress in the reduction of weight of the radial air-cooled type can be made by the use of magnesium in many places where aluminum is now used. Once an engine is built, increases in horsepower output reduce the specific weight to a greater degree than efforts to reduce sections, although lighter materials are being used to advantage.

Over-all dimensions of the powerplant have a great effect on the form of the airplane in which it is to be installed. The fore-and-aft dimensions, while not always important, frequently control the length of a small ship. The diameter of a radial engine often determines the size of the fuselage and the position of the pilot for forward vision, if any. The smaller the over-all dimensions of an engine, the more satisfactory is its installation.

Head-resistance of the powerplant grows in importance and assumes enormous proportions as the speed of airplanes increases. The uncowled radial air-cooled form is probably the worst possible for an engine for low head-resistance. The radial type would have lost much of its popularity for this reason were it not for the discovery of low-resistance ring-cowling, which confines the resistance of an engine to its own diameter, as shown in Fig. 9. A positive thrust component in the direction of flight is obtained from the air deflected to the rear by the ring. So far, the weight of experimental data indicates that the closer the ring can be placed to the propeller trailing edge, the lower the head-resistance and the better the cylinder cooling will be. There is also an optimum angle of incidence for the ring, which must be determined experimentally.

Gains in Speed from Cowls and Baffles

The large frontal area of a radial would suggest high head-resistance as compared to a V-engine, regardless of the cowl. Tests have indicated that this effect is less pronounced than would be expected. The surprisingly good performance of the radial engine is probably due to symmetry directly behind the propeller. If this is the case, the V-engine could be made symmetrical behind the propeller by changing its frontal dimensions to those of a radial engine. The V-engine would then lose much of its advantage, as its frontal area would be the same as that of a radial and its length and weight would be greater. The addition of an N.A.C.A. or ring cowl to a high-speed airplane has been known to increase its top speed as much as 20 m.p.h. To effect the same increase in performance in a 160-m.p.h. airplane would require approximately a change from 400 to 600 hp., as the speed of a plane varies as the cube of the engine output. The fuel consumption would then be 42.5 per cent greater, requiring greater fuel capacity and more wings of higher air resistance to carry the fuel. The tremendous advantage of a low-drag cowl is therefore apparent.

Strangely enough, the addition of intercylinder baffles, such as used on the Cyclone engine as seen in Fig. 7, has caused an increase in speed of 4 to 8 m.p.h. in every installation on which comparative data are available. This improved performance from the use of baffles might be expected in the case of the N.A.C.A. cowl with a wide exit slot, but was wholly unexpected with the ring cowl.

Reduction of diameter will, of course, decrease the drag of a cowled or uncowled engine, as it reduces the frontal area without changing its form. The engine designers' battle with engine diameter is a long and involved story, starting with bore-stroke ratio and extending to valve-rocker-box covers. Almost every detail of connecting-rod and cylinder design is subject to compromise to obtain the minimum diameter without sacrificing reliability by too great reductions in crank-pin diameter, master-rod sections, connecting-rod:stroke ratio, piston length or length of valve-springs. The L-head radial engine shows promise of greatly reduced engine diameter, as the valve-operating mechanism is below the top of the combustion-chamber. The diameter of an L-head radial can be from 6 to 10 in. less than that of an engine having the present hemispherical combustion-chamber, which will be of tremendous advantage to engine thrust-horsepower.

The maximum thrust-horsepower from a radial engine will therefore be obtained with small diameter and a ring or N.A.C.A. cowl. Since the cowling has such a great effect on cylinder cooling, the engine manufacturer should investigate this effect on his product and either make recommendations or, preferably, supply the cowls to order. The day may not be far ahead when every radial engine will be delivered equipped with a ring cowl.

High-speed airplanes are extremely sensitive to roughness in air-flow at any point. An exhaust pipe or a carbureter scoop which is not thoroughly worked into the installation can easily account for 10 m.p.h. in the speed of the airplane. The closest cooperation between engine designer and plane designer is therefore essential to prevent blunders in installation details which may counteract the effect of clever and careful design. An extensive program of flight tests with changes in installation details is the only way to arrive at the best solution of the problem, as wind-tunnel results are subject to scale error and fail to reveal propeller effects. The Curtiss-Wright organization has conducted a series of tests of this nature on the F8C5 and YP-20 airplanes with most satisfactory results. Close cooperation between the Curtiss and Wright divisions was necessary to make these tests possible. It is hoped that such co-

operation between manufacturers of planes and engines over a series of flight experiments will become the rule rather than the exception.

Propeller Efficiency and Gearing

The present form of conventional propeller loses efficiency rapidly at tip speeds above 950 ft. per sec. This condition frequently prevents improvement in performance from an increase in engine power at greater engine speed, as the efficiency of the propeller declines as fast as the power of the engine rises. Fortunately, the engine speed during taking off and climbing, which are the usual occasions for full-throttle operation, is 200 to 300 r.p.m. below that of the speed in straight-away flight, in which full throttle is seldom necessary. The tip-speed condition is greatly improved by this lower speed, making it possible for normal service airplanes which have serious propeller inefficiency in level full-throttle flight to operate with efficiency. Engines of under 300 hp. operating up to 2000 r.p.m. are not troubled by considerations of tip speed. Beyond this horsepower, at 2000 r.p.m. or faster, the effect becomes worse as the power output is increased. It is possible that the present airfoil sections for propeller blades can be altered to increase the permissible tip speed.

The forward motion of an airplane is produced entirely by accelerating air to the rear, giving the well-known equation for thrust of $F = MV^2$, where F is the thrust, M is the mass of air handled, and V is its mean velocity in a direction opposite to that of flight. From this equation it becomes obvious that, as the quantity of air, and therefore the propeller diameter, is increased, the velocity with which that air passes over the airplane will be greatly reduced. The reduction in relative velocity between the airplane and the slipstream cuts the interference losses, especially as the larger propeller-diameter removes much of the slipstream air from the immediate proximity of the fuselage. An increased propeller efficiency results from the use of large-diameter propellers at low rotative speed, especially in large slow-flying planes for which the thrust requirement is high and the speed requirement low.

The large propeller-diameter and low speed can be produced by a reduction in rotative speed of the engine, in which case the engine horsepower will be seriously affected, or by the use of reduction gears, in which case the weight of powerplant will be increased by 60 to 100 lb., due to the gears, and 50 to 150 lb. due to the larger propeller. On large airplanes the engine and propeller-weight increase is not serious, as it is a very small percentage of the total. On small ships an increase in height of landing gear may be required to provide propeller ground-clearance and an increase in wing area may be needed to maintain the landing speed with the added weight of engine, propeller and landing gear, resulting in a reduction in performance. The gains and losses must therefore be compared to determine the advisability of reduction gearing. Reduction gears, however, will be of increasing interest in the progress toward greater thrust-horsepower, as they remove the limit of propeller efficiency in relation to engine speed.

Powerplant designers will be able to utilize the increase in engine output derived from high-speed operation with no handicap to propeller efficiency by suitable gears. This gain is not without its problems, as slow-speed propellers with large hubs increase the difficulty of cylinder cooling because of the indefinite air-blast near the hub. Suitable cowling will do much to remove this restriction and make available the increase in thrust horsepower due to high crankshaft-speed with efficient propeller-speed.

The limit of possibilities in any of the lines of research for increased thrust-horsepower of radial engines as set forth in this paper has not yet been reached. The characteristics which appear most inflexible are the maximum of 14 cylinders on the two-row radial type and the maximum practicable size of air-cooled cylinder of somewhat over 215 cu. in. When an engine of this displacement has been developed to its limit of thrust horsepower, other developments may point the way toward future progress wherein the type may be abandoned; but recent developments producing increases in thrust horsepower indicate that the radial air-cooled type has not yet passed the adolescent period.

THE DISCUSSION

W. G. WALL[4]:—In the past we have been very glad to locate the spark-plugs in air-cooled engines where they could be kept cool, but forced cooling of spark-plugs may make it possible to place them wherever we wish. Excellent results have been obtained in motor-car engines during the last two or three years, especially in the valve-in-head type, by placing the plugs near the center of the combustion space. Whether this is due entirely to the more nearly equal distance of flame travel or partly to having the plug where the mixture is richer, as Mr. Lawrance has remarked, I cannot say, but such placing has been of great benefit in increasing the power. Has Mr. Taylor tried various spark-plug locations in aeronautic engines recently?

Another question is in regard to pistons. Aeronautic-engine designers have been very wise in sticking to trunk-type pistons as long as they could, as certain complications and trouble are found with any other type. This is especially true of the skeleton-type pistons, as the oil cannot be controlled in the cylinder by any type of piston-ring unless the piston travels parallel with the bore. Large clearances and certain types of piston allow piston rocking in the cylinder, so that too much oil gets into the cylinders at high speeds.

Some type of split-trunk piston might keep down not only the oil but also the clatter which comes in all airplane engines during the first few minutes after starting the engine. We are not so much interested in this just at present; but the time is rapidly coming when quieter planes will be wanted, and that means that quieter engines will be necessary. We are now padding the cabins of some of the large planes so that the noise will not penetrate, and improving propellers to reduce noise. Soon we shall be working on airplane engines to cut down the noise.

PHILIP B. TAYLOR:—The cylinder-heads of most air-cooled engines are so full of valves that choice of the spark-plug location is quite limited. We use two spark-plugs, placed diametrically opposite at the sides that are free from the valves, because that is the only place

[4] M.S.A.E.—Consulting engineer, Indianapolis.

where they will fit in. There is only ¼ in. at the center of the combustion-chamber between the valves. There is no chance to do much experimenting by moving the spark-plugs around, as the cylinder is already full of other things. When some other shape of a combustion-chamber is used, such as the L-head or the F-head, the spark-plugs can be relocated with undoubtedly better results.

Engine Noises Hard to Eliminate

A piston clearance of 0.030 in. in a 6-in. bore seems like a tremendous amount and causes a great deal of noise. We have been able to control the oil very successfully; the oil consumption of our big engines at high speed is something like 0.015 lb. per hp-hr. under normal conditions. The oil might be controlled more closely if the piston fit could be a little better. The piston fit improves from heat as the output of the engine is increased, but the piston never fits the cylinder; if it did, excessive pressure would immediately cause it to stick.

I am glad that the development of mufflers and quiet propellers is coming along slowly. If the noise of the exhaust and the propeller should be quieted suddenly, the engines would all be grounded immediately on account of the tremendous noise from the pistons, the supercharger gears and other parts.

I took a member of the sales department into the experimental laboratory a while ago and showed him a supercharger running at full speed with the crankcase cut away. He made for the door immediately, saying that he never would have flown an airplane if he had known that anything of that kind was going on inside. We have a valve-test apparatus which makes so much noise that it disturbs the men in the shop, and they object to its operation. The pistons are probably even worse than either of those noises, because they sound more like a stone-crusher. We have to do something to reduce the noise of these parts as quickly as we can, but it is a long job. Automobile engineers have done wonderful work in reducing the noise of engines, and we must follow their lead; but the noise problem is serious with an uncompensated valve-gear of considerable weight and with other parts designed for high output. I hope that mufflers and quiet propellers do not come too soon.

Test Temperatures Are High

NEIL MACCOULL[5]:—I wish to call attention to the fact that the Army specification for an octane number of 87 for aviation gasoline requires a jacket temperature in the test engine of 300 deg. fahr. That may be very different from a fuel that has an octane number of 87 at a lower temperature such as 212 deg. fahr., the usual temperature for motor-fuel tests.

MR. TAYLOR:—The jacket temperature which has been used in testing air-cooled and Prestone-cooled engines is 300 deg. fahr. There is some evidence that even this temperature is not high enough, as the curves for specific fuel consumption in relation to power and cylinder temperature, such as shown in Fig. 12, sometimes are not in the order of the octane rating of the fuel. Cracked fuels give such inverted curves even when tested with a cylinder-jacket temperature of 300 deg., so engine tests must be further developed to correctly simulate conditions in an air-cooled or Prestone-cooled engine.

EDWARD P. WARNER[6]:—I was surprised to note in Fig. 12, the curves of which I understand to be taken from a stock Cyclone engine with constant compression-ratio and the fuel consumption varied by changing the mixture, that so much difference in minimum fuel consumption is indicated at the left between fuels all of which are of high octane number. How much farther could the reduction in fuel consumption be carried by increasing the octane number?

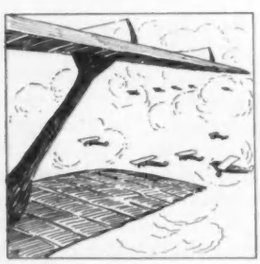
MR. TAYLOR:—I believe it could go somewhat further on this particular engine, possibly as low as 0.50 lb. per b.hp-hr. with fuel having an octane rating of 100.

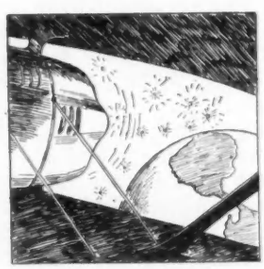
ROLAND CHILTON[7]:—I should like to emphasize for the benefit of fuel men the fact that our company, and I am sure other engine builders, have engines rated at say 300 hp. which, in their present state of development, could be put into service conservatively at 450 hp. provided aviation fuel was available having an iso-octane specification only a little higher than the rating of the common ethylized automobile fuel.

[5] M.S.A.E.—Automotive engineer, The Texas Co., New York City.

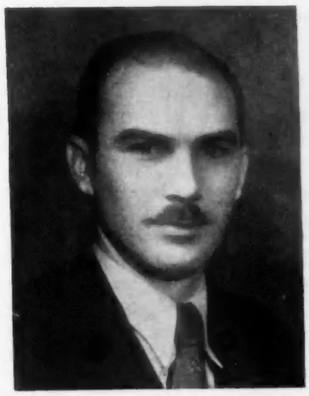
[6] M.S.A.E.—Editor, *Aviation*, McGraw-Hill Publishing Co., Inc., New York City.

[7] M.S.A.E.—Consulting engineer, Wright Aeronautical Corp., Paterson, N. J.





Oil Cooling and Oil-Coolers



Annual Meeting Paper

By W. R. Ramsaur[1]

INCREASES in horsepower, compression pressure and engine speed, which have occurred in the last five years, have imposed additional duties on the lubrication system, points out the author, who declares that bearing failure is the most serious trouble resulting on the road from the use of oil temperatures exceeding 300 deg. fahr. To reduce this temperature to a figure between 210 and 230 deg. fahr., heat must be dissipated from the oil at a rate in excess of 250 B.t.u. per min. or a heat equivalent of approximately 6 hp.

Two types of oil-cooler, one using air and the other water as the cooling medium, are available at present. The former is extensively employed in connection with air-cooled engines, particularly on airplanes, but the latter is in more general use on automobiles. After listing the six requirements of a satisfactory oil-temperature control-unit, the author describes a number of tests made to determine the relative effectiveness of the two types of cooler as regards the dissipation of heat from the oil. Charts giving the results of the various tests supplement the text.

The discussion brings out a number of interesting points, among which are the need for decreasing oil viscosity at low temperatures and increasing it at the higher values, the difficulty of predicting bearing temperatures due to the lack of fundamental data on lubrication, the progress made in dissipating heat by circulating oil, discrepancies in temperatures at various points in the oiling system and the reason for the differences in the heat-dissipating capacity of the three units described in the paper.

SINCE the introduction of internal-combustion engines, the lubricating system has undergone few fundamental changes. At the same time, other parts of the engine have made considerable advancement, which, in many cases, results in high oil temperatures. These changes that directly affect oil temperatures are

(1) Increased horsepower
(2) Increased compression-pressure
(3) Increased engine-speed

All of these factors impose additional duties on the lubrication system, originally designed to prevent a metal-to-metal contact and to assure a pressure seal.

Engine horsepower on automobiles, in some cases, is above 200, while, on airplanes, horsepowers in excess of 500 are not uncommon. During the last five years compression ratios[2] have increased from an average of 4.5 in 1925 to 5 in 1930, or 11 per cent. Compression pressures have increased from an average of approximately 80 lb. per sq. in. to 100, or 25 per cent, with a consequent increase in cylinder temperatures. The higher engine-speeds, resulting in more power per cubic inch, also increase the *pv* factors, which were at one time considered safe at 32,000, but which now, in some instances, run in excess of 60,000.

To lubricate an engine properly, an oil that is low enough in viscosity to permit easy cranking and a quick circulation to the bearings, regardless of the starting temperature, should be used. A rapid rate of warm-up of the oil is desirable to reduce crankcase-oil dilution and aid in lubrication. Under operating conditions, the oil should have high enough viscosity and sufficiently low temperature to insure engine safety and reliability. Without some method of oil-temperature control, from a viscosity standpoint alone, the use of a heavy oil to take care of high temperatures will produce high cranking torque and inadequate lubrication under winter starting conditions. If a light oil is used to facilitate cranking and lubrication at low temperatures, this oil will not have sufficient viscosity at high temperatures.

Considering, first, the subject of high oil-temperatures, oil temperatures on the road in excess of 300 deg. fahr. have been recorded. High oil-temperatures tend to cause the following troubles:

(1) Excessive oil consumption
(2) Smoking at the exhaust
(3) Fouled spark-plugs
(4) Formation of carbon in combustion-chamber due to excess oil
(5) Engine wear
(6) Failure of bearings

The most serious of these troubles is bearing failure. Some question has arisen as to how much protection a heavy oil furnishes the bearings, but unquestionably

[1] Development engineer, Harrison Radiator Corp., Lockport, N. Y.

[2] See *Automobile Topics*, June 28, 1930, p. 636.

babbitt metal rapidly loses its strength and hardness with an increase in temperature and the bearings may easily crack and pound out at much lower temperatures than those required to melt the babbitt. Circulating cool oil to the bearings will lower their temperatures and reduce failure. In addition, the bonding material, usually tin, will have the same characteristics with the low melting-temperature of 445 deg. fahr.

The Bureau of Standards chart of various bearing alloys, which is reproduced as Fig. 1, shows an average ultimate strength at 77 deg. fahr. of 14,400 lb. per sq. in., whereas at 212 deg. fahr. the ultimate strength has fallen off to an average of 6100 lb. per sq. in. An

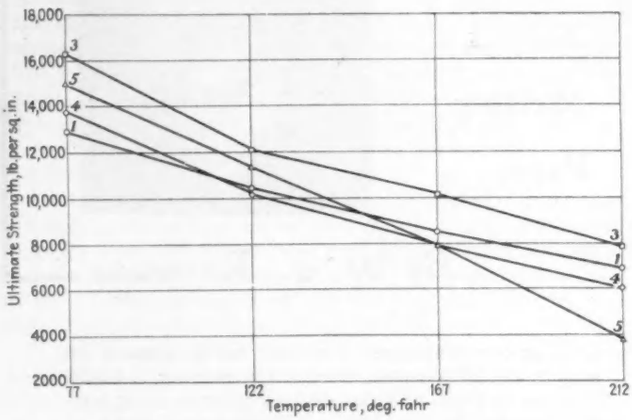


FIG. 1—CHART SHOWING THE DECREASE IN THE ULTIMATE STRENGTH OF BEARING ALLOYS WITH INCREASED TEMPERATURES

The Average of the Results Obtained by the Bureau of Standards, Which Prepared This Chart, Shows That for the Bearing Metals Represented the Ultimate Strength Decreases 615 Lb. per Sq. In. for Each 10-Deg. Fahr. Increase in Bearing Temperature. The Compositions of the Four Bearing Alloys Are Given Below

Bearing	1	3	4	5
Copper, per cent	4.56	5.65	2.90	...
Antimony, per cent	4.52	6.90	10.50	10.03
Lead, per cent	0.00	0.09	25.05	84.95
Iron, per cent	0.50	0.50	0.50	0.50
Tin, per cent	Remainder	Remainder	Remainder	Remainder

average of the above figures shows that each 10-deg. increase in bearing temperature represents a decrease in ultimate strength of 615 lb. per sq. in. Unfortunately, the range of this chart does not cover the temperature at which bearings fail, but will serve only to show the effect of low temperature on the strength of bearing metals.

Observations made on an engine in the cold room show that, if a heavy oil is used below its pour-point, the oil-pump will take up only a cavity in the oil reservoir, after which no more circulation, except dilution from choking, will occur, until the oil has received heat, which does not occur for several minutes. By using a light oil, this so-called dry period of lubrication can be minimized, since the light oils have lower pour-points and lower viscosity. A light oil furnishes instant lubrication to the moving parts and prevents wear and scuffing of the lubricated surfaces. With the light oil no cavitating of the pump at low temperatures occurs.

In addition to the lower pour-test, the decreased viscosity of the light oil will materially reduce the required cranking torque. Fig. 2 shows the required cranking torque at the starting-motor pinion for various oil-viscosities. These curves were made first with oils of different viscosities, keeping the engine at room temperature, and afterward with the same oil but varying the engine temperature in the cold room. This investigation showed that the required cranking torque was proportional to oil viscosity only and any variation was not caused by change in engine clearances due to changes in temperature. When the viscosity of light and heavy oils is considered, these curves show that the same power is required to crank the engine at 27 deg. fahr., with the light oil as is required with the heavy oil at 67 deg. fahr. While the required cranking torque is high at low temperatures, the available torque is reduced due to the decreased voltage of the battery, thus making starting difficult. By the use of a light oil with its viscosity and temperature controlled, dangerously high temperatures, with loss of viscosity, and equally dangerous low temperatures, with inadequate lubrication, are avoided.

Fig. 3 shows a chart of S.A.E. oils, which demonstrates that a heavy oil, S.A.E. No. 40, at 300 deg. fahr., has a lower viscosity than a light oil, S.A.E. No. 10, at a temperature of 210 deg. fahr. The heavy oil has a viscosity of 42 sec. at 300 deg. fahr., whereas the light oil has a viscosity of 46 sec. at 210 deg. fahr.

Recognizing the necessity of meeting changing conditions, much time and thought have been devoted by automotive engineers to the subject of regulating oil temperatures and to the development of devices to prevent, as far as possible, the lubrication troubles that have been encountered.

In approaching a problem of this nature, we find that on some engines to reduce the oil temperature from above 300 deg. fahr. to a satisfactory temperature of around 210 to 230 deg. fahr. dissipating heat from the

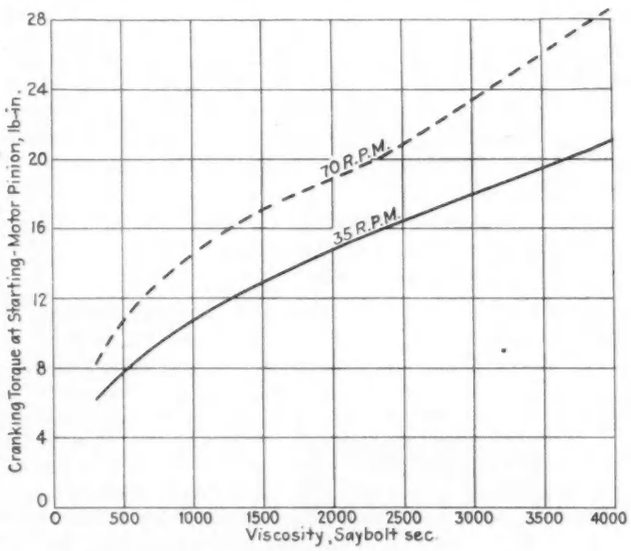


FIG. 2—REQUIRED CRANKING TORQUE AT THE STARTING-MOTOR PINION FOR VARIOUS VISCOSITIES

The Curves Were First Obtained with Oils of Different Viscosities and the Engine at Room Temperature. In a Second Series of Tests the Same Oil Was Used Throughout, but the Engine Temperature Was Varied in the Cold Room. This Investigation Showed That the Torque Required To Turn the Engine Over Was Proportional to the Oil Viscosity Alone and Any Variation Was Not the Result of Changes in Engine Clearances Due to Changes in Temperature

oil at a rate in excess of 250 B.t.u. per min., or a heat equivalent of about 6 hp., is necessary. Thus the problem of oil-temperature control resolves itself into the selection of suitable oil-coolers or heat-exchange units to remove this waste heat.

Air and Water-Type Oil-Coolers Compared

At present, two types of oil-cooler are in use: (*a*) the air-type cooler, which uses air as a cooling medium, and (*b*) the water-type cooler, which uses water as the cooling medium. The former is largely used on air-cooled engines, especially on airplanes, where its use is very extensive. The water-type coolers are in more general use on automobiles than the air type.

A satisfactory oil-temperature control-unit should

(1) Warm the oil when cold
(2) Cool the oil when hot
(3) Be as free from restriction of oil-flow as possible
(4) Be as free from plugging as possible
(5) Be accessible and easily cleaned
(6) Withstand a continuous pressure of at least 100 lb. per sq. in.

Numerous tests show that after starting most engines a considerable lag in oil temperature, as compared with water temperature, occurs. If a water-type unit is placed in the water circuit, a rapid rate of warm-up may be expected, provided the water system is thermostatically or shutter controlled. In respect to warm-up, the water-cooled unit has the advantage over the air type, although the latter may use a thermostat to bypass the oil when cold.

The temperature reduction expected from an oil-cooler installation depends largely on the size of the

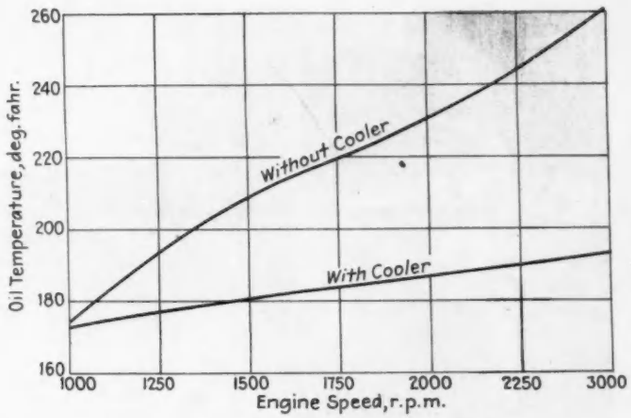


FIG. 4—COMPARISON OF OIL TEMPERATURES WITH A WATER-TYPE OIL-COOLER INSTALLED AND WITH IT REMOVED

These Results Were Obtained in Both Cases by Running the Engine on a Dynamometer Stand and Keeping the Temperature of the Bottom Tank of the Radiator Constant at 170 Deg. Fahr. The Only Temperature Which Did Not Become Stable Was That for the 2500-R.P.M. Run without the Oil-Cooler

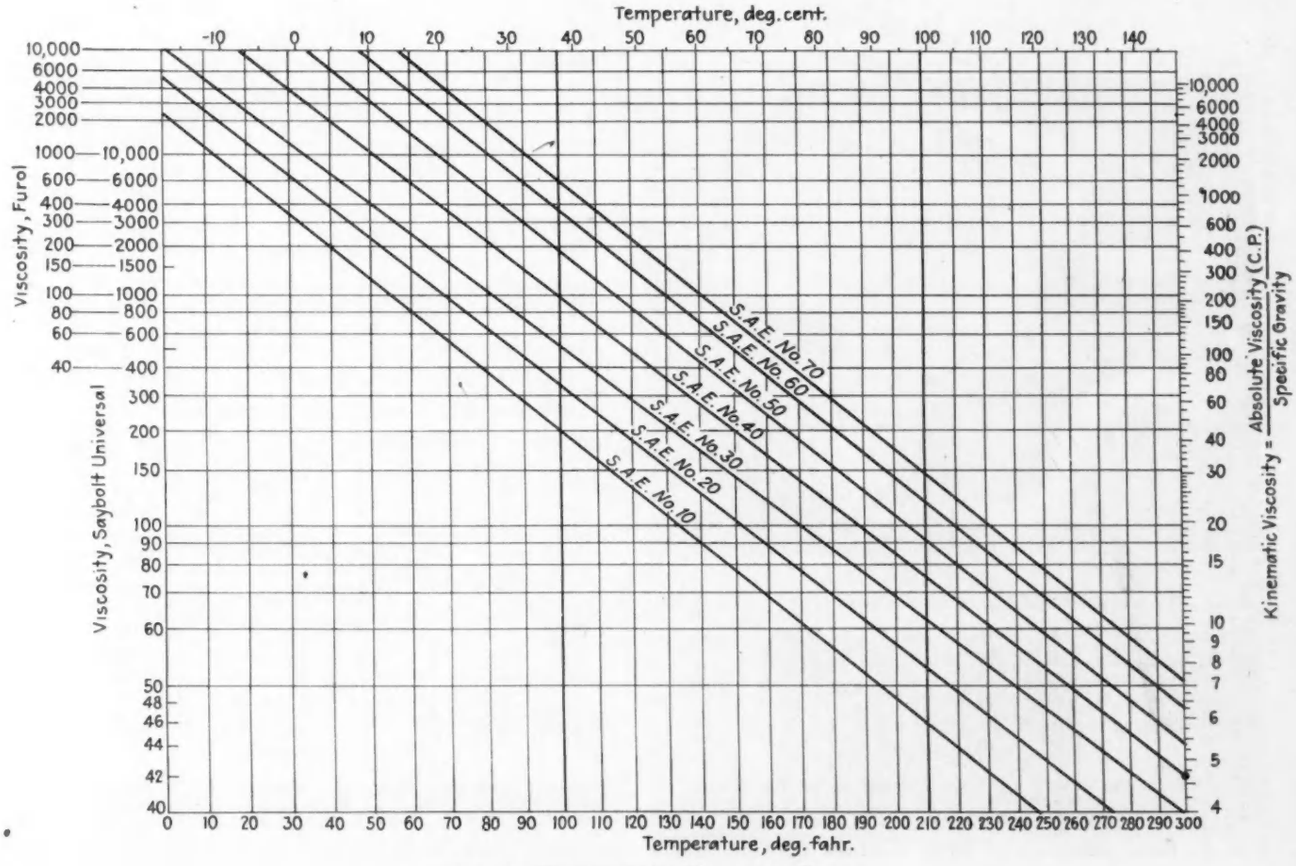


FIG. 3—TEMPERATURE-VISCOSITY CHART

This Chart Shows the Effect of Temperature on the Viscosity of an Oil and That at a High Temperature a Normally Heavy Oil May Have a Lower Viscosity than a Lighter Oil at a Lower Temperature

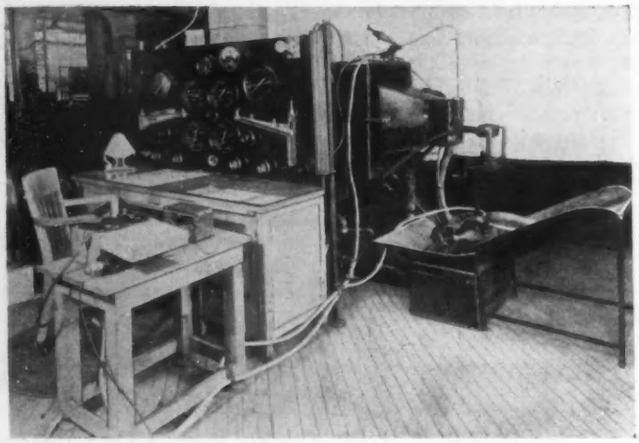


FIG. 5—SET-UP FOR HEAT-REJECTION TESTS

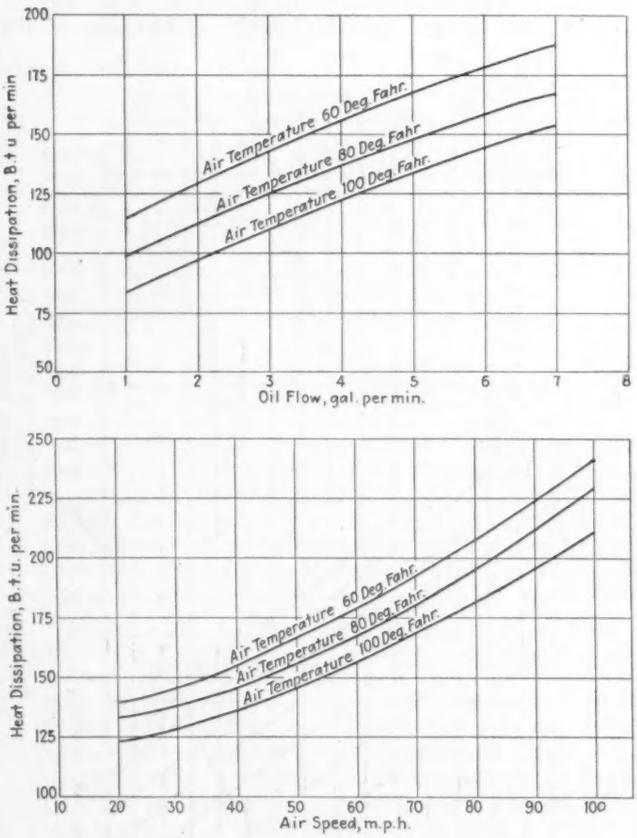
In These Tests a Cooler Having 161 Tubes Was Mounted on a Dissipator So That Either Water or Air Could Be Passed through the Cooler

cooler employed. On the present installations, the temperature reductions lie between 50 and 100 deg. fahr. The effectiveness of reduced oil-temperature is best shown by one of the tests run with a car on the test track. The car was run 200 miles at 80 m.p.h. with a cooler with a maximum oil-temperature of 215 deg. fahr. With the cooler removed, the car under the same conditions ran less than 50 miles, the bearings failing when the oil reached 275 deg. fahr., although the oil temperature was still rising. The air temperature was 75 deg. fahr. in both runs.

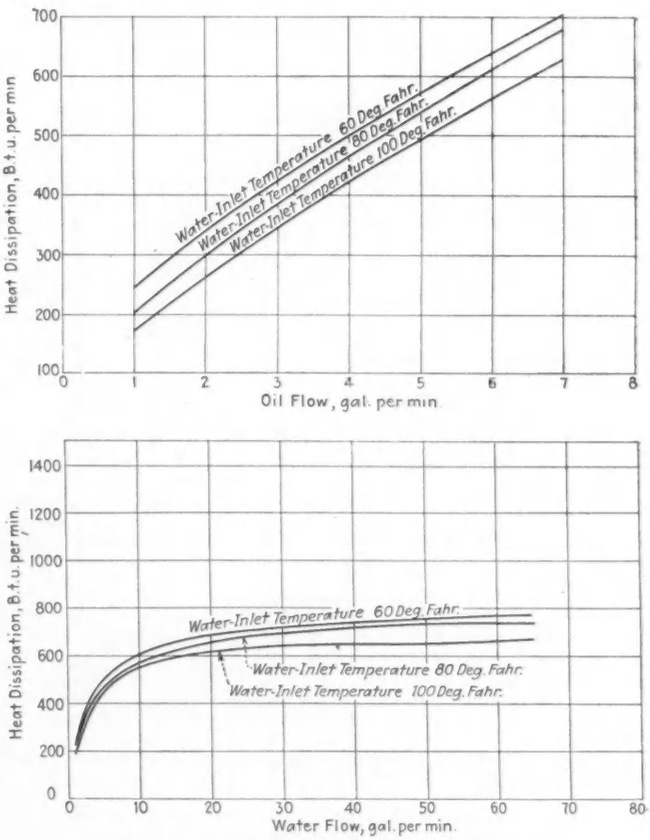
Fig. 4 shows the oil temperature of an engine on the dynamometer stand, with and without a water-type cooler, the only temperature that did not stabilize being that in the run at 2500 r.p.m. without the cooler. During this test, the bottom tank of the radiator was held at a constant temperature of 170 deg. fahr.

Likelihood of Cooler Plugging

With any device of this character, which must pass oil regardless of its purity or condition, the question of possible plugging must be considered. As bearing on this, a severe track test was run. A car with cast-iron pistons was driven 28,000 miles at a minimum speed of 60 m.p.h. The oil was not changed during this time, but was added to at intervals as needed by the engine. At the conclusion of this test an inspection of the cooler showed that sufficient carbon particles had accumulated to affect seriously the oil-flow through the core.


Heat Dissipation, B.t.u. per min
Air Temperature 60 Deg. Fahr.
Air Temperature 80 Deg. Fahr.
Air Temperature 100 Deg. Fahr.
Oil Flow, gal. per min.
Heat Dissipation, B.t.u. per min.
Air Temperature 60 Deg. Fahr.
Air Temperature 80 Deg. Fahr.
Air Temperature 100 Deg. Fahr.
Air Speed, m.p.h.

Air-Cooling at a Constant Air-Speed of 60 M.P.H.
Air-Cooling at Air Speeds Ranging from 20 to a Maximum of 100 M.P.H.


Heat Dissipation, B.t.u. per min
Water-Inlet Temperature 60 Deg. Fahr.
Water-Inlet Temperature 80 Deg. Fahr.
Water-Inlet Temperature 100 Deg. Fahr.
Oil Flow, gal. per min.
Heat Dissipation, B.t.u. per min.
Water-Inlet Temperature 60 Deg. Fahr.
Water-Inlet Temperature 80 Deg. Fahr.
Water-Inlet Temperature 100 Deg. Fahr.
Water Flow, gal. per min.

Water-Cooling at a Constant Flow-Rate of 25 Gal. per Min.
Water-Cooling at Various Flow-Rates with 65 Gal. per Min. as the Maximum

FIG. 6—HEAT DISSIPATION WITH VARIOUS COOLING MEDIA AND FLOW RATES FROM AN OIL TEMPERATURE OF 210 DEG. FAHR.

Measurements Were Made in All Cases at Air or Water Temperatures of 60, 80 and 100 Deg. Fahr. In the Tests Represented by the Upper Pair of Charts, the Rate of Oil-Flow Varied, While in Those of the Lower Pair, the Flow Was Maintained Constant at 7 Gal. per Min.

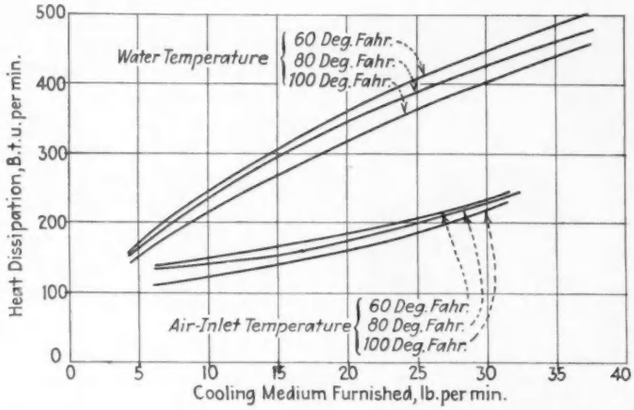


FIG. 7—COMPARISON OF AIR AND WATER AS A COOLING MEDIUM FOR OIL AT A TEMPERATURE OF 210 DEG. FAHR.

This Comparison, Which Was Based on Supplying the Same Weight of Cooling Medium per Minute in Each Case at Temperatures of 60, 80 and 100 Deg. Fahr., Showed That the Water-Type Oil-Cooler Was Better than the Air Type, Due Principally to the Low Specific-Heat and Low Specific-Weight of Air as Compared with Water

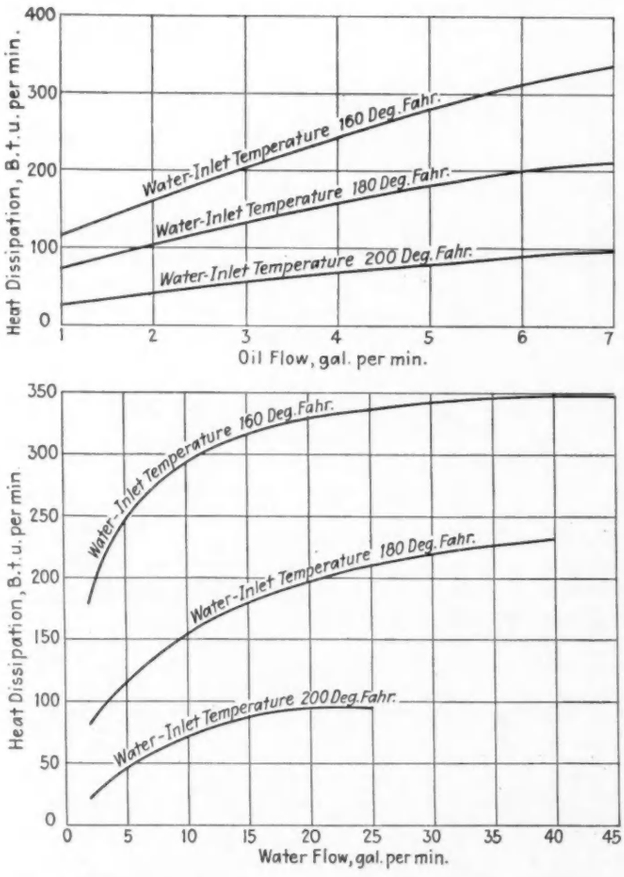

Heat Dissipation, B.t.u. per min.
Water-Inlet Temperature 160 Deg. Fahr.
Water-Inlet Temperature 180 Deg. Fahr.
Water-Inlet Temperature 200 Deg. Fahr.
Oil Flow, gal. per min.
Heat Dissipation, B.t.u. per min
Water-Inlet Temperature 160 Deg. Fahr.
Water-Inlet Temperature 180 Deg. Fahr.
Water-Inlet Temperature 200 Deg. Fahr.
Water Flow, gal. per min.

FIG. 8—HEAT DISSIPATION OF A WATER-TYPE OIL-COOLER AT AN OIL TEMPERATURE OF 210 DEG. FAHR. AND WATER-INLET TEMPERATURES OF 160, 180 AND 200 DEG. FAHR.

In the Upper Chart the Water-Flow Was Constant at 25 Gal. per Min. and the Oil-Flow Rate Varied. In the Lower Chart the Water-Flow Rate Was the Variable and the Oil-Flow Was Constant at 7 Gal. per Min.

Even in view of this severe test and the fact that no plugging complaints have as yet been received about those in service, we recommend that the cooler be cleaned out with benzol after every 20,000 miles. As a further safeguard to assure flow to bearings, a bypass should be connected around the cooler.

The ability of coolers to withstand pressure is essential. As experience in manufacture has increased, oil-cooler failures have been practically eliminated.

Heat Rejection

The quantity of heat that can be rejected from a cooler of a given size depends largely upon the temperature difference between the oil and cooling medium and the nature of the cooling medium, whether oil or water. To determine the quantity of heat rejected under conditions of operation that are likely to be encountered, tests were conducted on a medium-size cooler having 161 tubes, which was set up on a dissipator, Fig. 5, so that either water or air could be passed through this cooler. The oil used in these tests had a viscosity of S.A.E. No. 30 and in all cases was circulated to the cooler inlet at a temperature of 210 deg. fahr. The heat dissipation at various rates of oil-flow with air temperatures of 60, 80 and 100 deg. fahr. with the air speed constant at 60 m.p.h. is shown in the chart at the upper left of Fig. 6. The chart at the upper right shows this cooler as a water-type unit under the same conditions of temperature but with a water-flow of 25 gal. per min. The dissipation of the air-type unit at air speeds of 20 to 100 m.p.h. with air temperatures of 60, 80 and 100 deg. fahr. is shown in

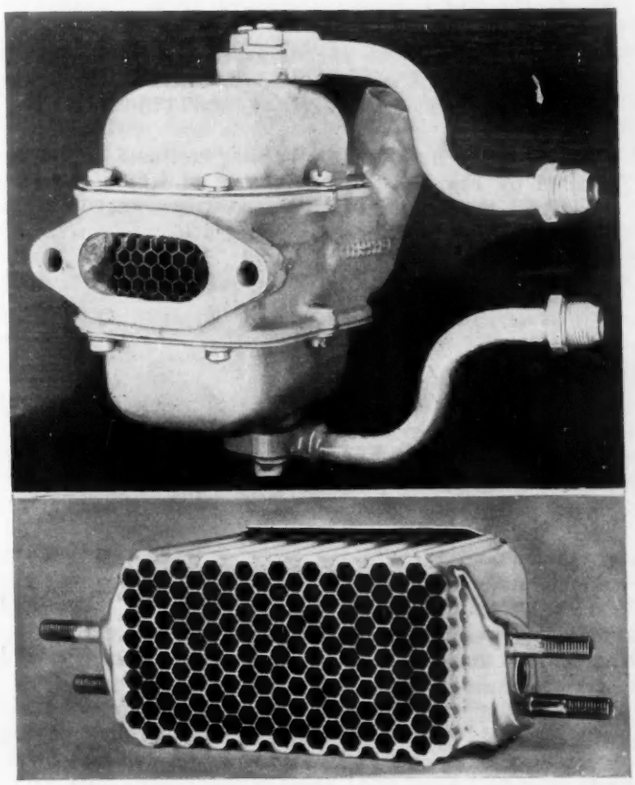


FIG. 9—TWO TYPES OF OIL-COOLER HAVING 161 TUBES

The Upper Photograph Is of the Water Type, While the Air Type Tested, with Water Headers Removed, Is Shown Below

the chart at the lower left. The oil-flow was held constant at 7 gal. per min. during this test.

The chart at the lower right presents the results of a similar test on this unit run as a water type, with water-flows up to 65 gal. per min. A comparison of this cooler with the same number of pounds of cooling material—water and air—furnished to the cooler is given in Fig. 7. Under the same conditions of temperature, we find that the water-type cooler has a considerable advantage over the air type. The reason for this is largely due to the low specific-weight and low specific-heat of air in comparison with water. Obviously, low water-temperatures of from 60 to 100 deg. fahr. can be obtained only in the dynamometer room or in boat service and cannot be obtained on the road.

The upper chart in Fig. 8 shows the heat dissipation of the water-type unit at water temperatures of 160, 180 and 200 deg. fahr. and various oil-flows, but with a constant water-flow of 25 gal. per min. On the lower chart is shown the heat dissipation at varied water-flows, with a constant oil-flow of 7 gal. per min., the water temperatures being 160, 180 and 200 deg. fahr. as in the other test. The conclusion to be drawn from these curves is that on a cooler of this size, when we consider the available air-temperature and velocity with the available water-temperature and velocity, the water-type cooler with water at 180 deg. fahr. is comparable with the air-type cooler with air at 100 deg. fahr.

Photographs of the 161-tube cooler used in these tests are reproduced as Fig. 9. The cooler, used as a water type, is shown in the upper view, while the lower shows the water headers removed from the air type that was tested.

The dissipation that can be expected from coolers of different sizes is shown in Fig. 10, where a comparison is made between the 112, 161 and 178-tube water-type coolers.

The effectiveness of an oil-cooler can best be demonstrated by Fig. 11, the two charts of which show respectively the control of oil temperatures in both summer and winter which can be gained by a correctly installed oil-cooler.

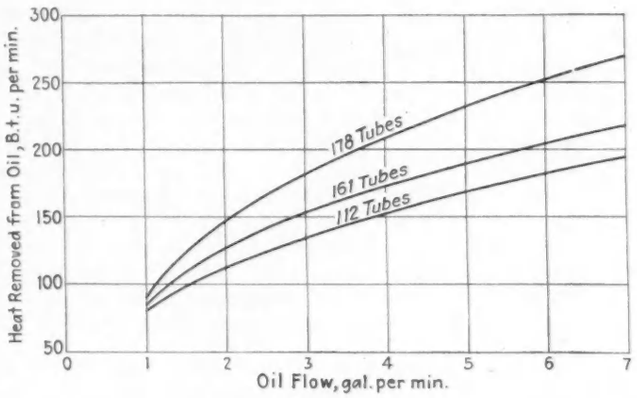


FIG. 10—HEAT DISSIPATION FROM COOLERS OF DIFFERENT SIZE

The Curves Show the Predicted Heat Dissipation with an Oil-Inlet Temperature of 210 Deg. Fahr., a Water-Inlet Temperature of 170 Deg. Fahr. and a Water-Flow Rate of 15 Gal. per Min. for Coolers Having 112, 161 and 178 Tubes of Hexagonal Cross-Section and a Wall Thickness of 0.27 In.

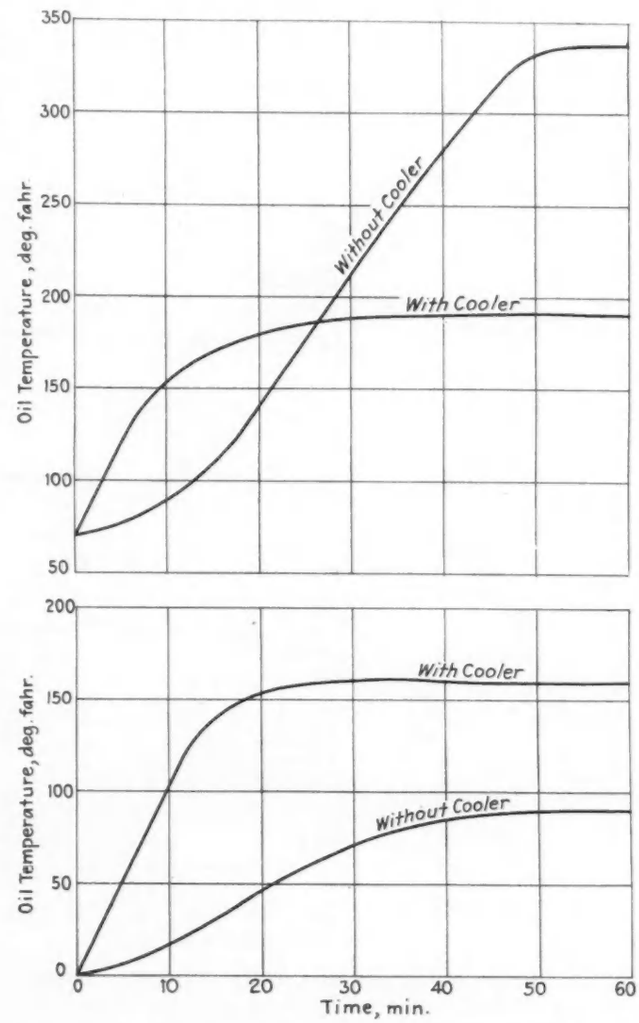


FIG. 11—OIL-TEMPERATURE CONTROL RESULTING FROM INSTALLATION OF AN OIL-COOLER

The Upper Chart Is for High-Speed Summer Operation and the Lower Is for Winter Operation in Traffic

THE DISCUSSION

ABBOT A. LANE[3]:—The form in which the figures were given rather surprised me. They are probably very interesting in the particular application of an oil-cooler, but I think Mr. Ramsaur ought to add also the results obtained in the form of British thermal units per square foot per degree temperature difference per hour. I did not see any indication of the number of square feet that he had in the area of the cooler. I think he also ought to give the water and air velocities and pressure drops, as they are very important factors affecting the coefficients of friction and of heat transfer.

ALEX TAUB[4]:—The most interesting part of this paper to me is that it again is obvious that, if the accessory manufacturers continue to develop new products, we shall have good engines some day. The point

[3] M.S.A.E.—Mechanical engineer, Gulf Companies Research Laboratories, Pittsburgh.

[4] M.S.A.E.—Development engineer, Chevrolet Motor Co., Detroit.

is that the oil-cooler is here, not because an effort is being made to give the public a little better job, but because it has become absolutely essential. We are arriving at a point where we cannot get along without it.

ALEX TAUB

Some time ago I read a paper on engine economics[5] and was criticized because I advocated lower-speed large engines in place of high-speed smaller engines. Those who criticized have increased their engine sizes this year in spite of their stated opinion. However, they have done nothing about decreasing operating speeds or increasing their bearing ability. I believe we shall hear much about oil-coolers in the near future, and eventually they will be universally used. We seem unable to comprehend the significance of the very high oil-temperatures that exist under high-duty operation, and very often engineers appear unwilling to believe that such high temperatures exist.

We speak glibly about high *pv*'s. We know, however, that 30,000 *pv* is bad enough, yet we produce engines that must operate at 45,000 to 60,000 *pv* without any material change in the elements that control bearing life. The least that can be done will be to arrange for reduction in the resulting temperatures by oil cooling.

Oil-Heater Should Receive Attention

CHAIRMAN H. C. MOUGEY[6]:—We have stressed, this afternoon, the importance of the oil-cooler in summer, but I think that not enough attention has been paid to the oil-heater in winter. To my way of thinking, the greatest benefit that we derive from this device is the aid it gives in cold-weather starting. All the summer results, I think, are more or less "velvet" added to the winter advantages that we have.

GORDON MCINTYRE[7]:—In Canada we have conditions that are much more severe than those experienced south of the boundary line. The oil industry has been endeavoring to approach the problem from an altogether different viewpoint, that of decreasing the viscosity of the oil at low temperatures, and, if possible, increasing it at high temperatures. Of course, the ideal has never been reached but has been closely approached. I think that this system of oil cooling and, what is more important, oil warming, is an ideal thing from our point of view in Canada; that is, with our engines we will not encounter the difficulties that we do at 40 deg. below zero, and we shall be able to lubricate with some degree of satisfaction the cars that are running on our prairies. We in the oil industry, however, must not let this divert our attention from a problem that is strictly ours; namely, that of producing an oil for winter use having a flat viscosity-curve and a low cold-test.

Prediction of Bearing Temperatures Difficult

R. N. JANEWAY[8]:—Oil-coolers are rapidly becoming necessary to bearing life because of the increasing severity of loads and speeds brought about by the trend toward higher-output engines. One of the big troubles today in engine design is the inability to predict what bearing temperatures will be. This, to a great extent, is due to the lack of fundamental data on lubrication under the conditions that obtain in our engines. If anybody takes the trouble to investigate the subject of lubrication as limited to existing data, he will find that the information is confined to a range of speeds and loads which is far below those of our present-day engine conditions; so today designers are really working in the dark so far as knowing whether their design will be safe in operation or not. Added to this condition is the failure on the part of many designers even to take into account the *pv* with which the engine will be burdened, but even if the *pv*'s are known, whether they are safe is still open to the judgment of the designer. The crying need here is for some fundamental data that would tie up *pv*'s with the temperature differential between the bearing and the oil that is required to dissipate the heat produced as friction.

A. W. SCARRATT[9]:—With reference to Fig. 11, which shows the comparison of winter operation in traffic with and without the oil-cooler, I did not hear any mention of the water temperatures that existed throughout the range of operation with the oil-cooler, and I wonder how the attitude of the public in general toward disregarding a proper water-temperature of the engine will affect the performance of this unit.

In the comparison of the three sizes of oil-cooler that was given in Fig. 10, why is the increase in cooling capacity between the 112 and the 161-tube elements so little and the difference in cooling capacity between the 161 and the 178-tube elements so large?

H. C. MOUGEY

The *pv* Factor as a Measure of Heat Generated

R. E. WILSON[10]:—Mr. Taub has referred to the *pv* product of certain bearings and Mr. Janeway said that someone ought to determine the relationship between the *pv* of bearings and the quantity of heat generated or the temperature produced in the bearing. I venture to make the assertion that such a relationship will never be discovered, because none exists; in fact, as I have pointed out previously, this whole proposition is a red herring dragged across the trail of a real analysis of what goes on in a bearing.

The two factors of speed and load do not work in the same direction on any one factor that affects the behavior of a bearing. Suppose we have a bearing that

[5] See S.A.E. JOURNAL, March, 1929, p. 282.

[6] M.S.A.E.—Chief chemist and assistant technical director, General Motors Corp. Research Laboratories, Detroit.

[7] M.S.A.E.—Chief chemist, Imperial Oil Refineries, Ltd., Sarnia, Ont., Canada.

[8] M.S.A.E.—Consulting engineer, Detroit.

[9] M.S.A.E.—Chief engineer on motor-trucks and motorcoaches, International Harvester Co., Chicago.

[10] M.S.A.E.—Assistant to vice-president in charge of manufacturing, and head of development and patent department, Standard Oil Co. of Indiana, Chicago.

R. E. WILSON

is carrying such a heavy load that the point of film rupture is approached. If the *pv* product is a true indication of the severity of service, the logical thing to do would be to *decrease* the speed and thus decrease *pv*, but, as a matter of fact, the proper thing to do is to *increase* the speed so that the bearing can carry *more* load. The speed of the bearing is important in determining the bearing temperature; in fact, the temperature developed is approximately determined by the product of the speed and the viscosity of the oil in the bearing and is practically *independent* of the *load* on the bearing. Overheating of bearings under conditions of fluid-film lubrication is therefore a function of speed times *viscosity*. The tendency to rupture the bearing film, however, is a function of the pressure on the bearing and can best be counteracted by the use of high speeds and high viscosities, the very two things that tend to cause overheating. As long as we consider *pv* together simply because they are two factors that may cause two very different kinds of bearing failure, and try to measure the general severity of bearing conditions by that means, just so long will we be unable to intelligently design our bearings to meet different conditions of service.[11]

MR. JANEWAY:—Mr. Wilson repudiates the use of the *pv* factor as a criterion for bearing-friction work on the assumption that automotive-engine bearings operate with perfect film-lubrication under all conditions of load and speed. In the range of perfect film-lubrication, the friction is independent of the load, as is well known. The truth of Mr. Wilson's contention, therefore, depends upon the validity of the assumption regarding the existence of perfect film-lubrication.

R. N. JANEWAY

From a practical point of view, accepting this assumption is difficult. Anyone who has examined a set of engine bearings after their sustained operation at high speed must conclude from the abrasion of the bearing surfaces that the journals and bearings have not been continuously separated by an oil film.

No conclusive experimental data exist or have, at least, been published to establish the laws of bearing friction under the conditions existing in the automotive engine. The available data comprising the work of such authorities as Tower, Stribeck, Lasche and Kingsbury[12] cover a range of operating conditions of load, speed and lubrication means far removed from those with which we are concerned in the high-speed automotive engine. These same data furnished the basis for a paper by Mr. Wilson and D. P. Barnard, 4th, on The Mechanism of Lubrication[13].

Tower's experiments showed that within a limited range of bearing pressures and velocities, with bath lubrication, the coefficient of friction was proportional to the square root of velocity and inversely proportional to pressure. This range of velocity was from 100 to 500 ft. per min. and up to 350 lb. per sq. in. pressure. At pressures beyond this, up to 600 lb. per sq. in., the coefficient remained practically constant for a given velocity, increasing, however, as seizure was approached. The indication is that, in these experiments, the limiting pressure for perfect film maintenance was in the neighborhood of 350 lb. per sq. in. Stribeck and Lasche extended the experimental range beyond a velocity of 2000 ft. per min. Lasche found that in this range the coefficient was independent of velocity but varied inversely as pressure and temperature. That the maximum pressure carried was 213 lb. per sq. in. at about 2000 ft. per min. is significant, however. In the application of this experience to steam-turbine bearings running at 1800 to 3000 ft. per min., Kingsbury found that the safe pressure varies *inversely* as velocity so that the limiting factor becomes *pv*, which is taken empirically at 150,000 ft-lb. per sq. in. per min.

GORDON MCINTYRE

Compared with this explored range of bearing conditions, we have to contend in our engines with pressures of 1500 lb. per sq. in. and more, combined with velocities of over 2000 ft. per min., giving *pv* values of over 3,000,000, or 20 times the limiting figure accepted for steam turbines. This relatively terrific bearing duty under which our present engines operate has been made possible only by development of the pressure-feed lubrication system. However, this has not only been fully taken advantage of but is today being abused to the point where prolonged running is usually impossible at the maximum operating speed.

In the absence of definite data on the coefficient of friction under the actual conditions of operation, it is reasonable to assume from the foregoing discussion that the coefficient of friction tends to remain constant at high speeds and loads, especially in the critical range. From the empirical standpoint, which we are forced to take, the *pv* factor must be considered as the measure of heat generation.

Progress Made in Heat Dissipation

DR. H. C. DICKINSON[14]:—I should like to endorse what has just been said about bearings. Considerably more information is available on that subject than has ever been used by the designing engineers. That applies not only to the safe load-carrying capacity of the

[11] See THE JOURNAL, July, 1922, p. 49; also August, 1925, p. 205.

[12] For a summary of these data see Elements of Machine Design, by Kimball and Barr.

[13] See THE JOURNAL, July, 1922, p. 49.

[14] M.S.A.E.—Chief of the heat and power division, Bureau of Standards, City of Washington.

bearings and the heat dissipated, or to be dissipated, but also to the ability of oil to dissipate heat.

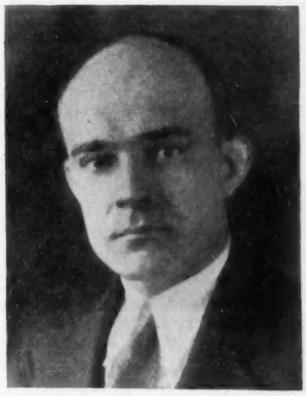
However, I should like to mention another phase of the whole subject. Sometimes, as a problem becomes more and more complicated, going back and seeing just where we started from is very interesting. In the lubrication of automobile engines 20 years or so ago, to put some fresh oil, occasionally a drop or so, into the various journals and let it spatter around on the cylinder-walls was a simple matter. Fresh oil was supplied to the journals and everything went well as long as we did not have too much heat to dissipate. Then speeds and loads increased and dissipating a considerable quantity of heat—more than could be carried away by metallic conduction in the crankcase—became necessary. That was easily accomplished by circulating oil. However, oil is about the worst possible material that one would be likely to use to dissipate heat. It has about one-half the heat capacity per unit volume that water has, and for other reasons it must have a very much higher viscosity than other materials which might be used for heat dissipation alone. It is difficult to cool. The viscosity changes with temperature so fast that any reasonable kind of a cooling system does not work well. In fact, we have seen cases of oil-coolers where the colder we made the circulating water, the hotter became the oil that passed through the cooler. This is a peculiar condition that will occur sometimes but illustrates a real difficulty. However, oil circulation was a very good compromise as long as the problem was simple. Circulating some oil and carrying away a small quantity of heat was successful as long as it could be done easily, in spite of the fact that we circulated dirt and so forth through the bearings.

The problem has now reached another stage that is much more difficult. The ordinary circulation of oil in the crankcase will not carry away enough heat. We have to do something else about it. In other words, we have to hang a few more gadgets on the Christmas tree. That being the case, I think some studiously inclined engineer could very well study the question whether, after all, oil is the best medium for carrying the heat away. The problem of carrying away the heat from bearings is a different and distinct problem from that of lubrication. Trying to do the two things at the same time complicates the whole matter. Maybe we might be able to do it some other way. If so, then we could design an oil and oiling system to do the lubricating effectively without increasing wear, and might also be able to design some system that would carry away the heat and effectively take care of the thermal problems that we must meet. I have no solution for the problem. The only obvious suggestion is that perhaps the water-cooled-engine people can get the water where it will carry away the heat from the bearings. I should like to see some engineer think hard on the subject.

DR. H. C. DICKINSON

A Car Manufacturer's Experience

C. T. DOMAN[15]:—As the author has confined his remarks to the water-cooled engine, perhaps a few words concerning the application of an oil-cooler to an air-cooled engine will be of interest. On a group of engines recently sold to the Government by the Franklin company for use in 7-ton Army tanks, temperatures of 300 deg. fahr. were found in the oil leads going to the bearings. The high temperatures were brought about by the fact that the engine was totally enclosed in a steel box to which air is admitted only through a duct leading to the cooling fan. The installation of a Harrison oil-cooler reduced the temperature to approximately 200 deg. fahr. We feel that this is a fine demonstration of the effectiveness of this cooler. Before the installation, satisfactory oil pressures could not be maintained when the engine was run.



C. T. DOMAN

I think that at times we do not get to the bottom of the reason for the oil temperatures which we feel exist in our engines. We can place a long-distance thermometer in the oil sump and get one temperature and then put a thermocouple in the oil line going to the bearing and get an entirely different reading. We recently surveyed the temperature in an oil sump and noticed 120 deg. fahr. difference between oil temperatures measured 1 in. above the lower surface of the pan and the oil entering the pump. These readings were observed with an outside temperature of 60 deg. fahr. Application of the brakes two or three times churned up the oil so much that the temperature difference in the oil sump was not more than 25 or 30 deg. Consequently, we gave up studying oil-sump temperatures and confined our work to temperatures of the oil going to each bearing.

In developing an oil-cooler for the tank engines, we built several coolers according to our own ideas. One of these coolers had 350 copper tubes of $\frac{3}{8}$-in. diameter. The oil from the engine dripped down through the tubes and goes into a separate sump and then into the oil-pump. Air was directed from the blower across these tubes.

On one of the tests it was noticed that the oil temperature would hover around 212 deg. fahr. and then gradually creep up to 250 deg. fahr. If the engine was sub-

(*Concluded on p.* 446)

A. W. SCARRATT

[15] M.S.A.E.—Research engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

Marine *versus* Converted Automobile Engines

Motorboat Meeting Paper

By R. H. Garrison[1]

GREAT differences in the service requirements and operating conditions for motor-car and motorboat engines are pointed out as reasons why the converted engine designed for automobile use is inferior to the marine engine for marine service.

The necessity of placing the flywheel and the reverse gear at opposite ends of the crankshaft calls for a large main bearing at the front end as well as at the rear end. Quick and easy accessibility of the bearings, connecting-rods, pistons and other internal parts calls for large handhole plates and for the removal of the cylinder-block without removing the crankcase from the engine bed. Heavy thrust loads imposed suddenly on the engine by the propeller require numerous and large hold-down bolts to secure the engine base to the engine bed.

Marine engines usually are installed at an angle, hence the water passages must be designed to avoid steam pockets. As the engine operates at full load and high speed most of the time, ample cooling must be provided, and good practice is to allow ample water space between the cylinders, surround the exhaust manifold with a water-jacket and to water-cool the valves and spark-plugs. Provision must be made against rusting by salt water and for cleaning deposits of salt and dirt out of the water-jacket.

Twin-screw installations call for true right-hand and left-hand engines, and automobile engines are not made in both types. Both light-weight high-speed and slow-speed heavy-duty engines are needed for marine service, which presents a wide variety of operating requirements. Compression and oil leaks present a serious trouble in marine service, and marine-engine builders have corrected these defects by design changes.

Automobile engines are not built for such long service-life as are the marine engines and, when a model is changed or discontinued, replacement parts are difficult to obtain after a few years.

The claim that marine-engine production is not on a large enough scale to justify equipping a factory with the necessary machinery is said to be disproved by a trip through one of the better-equipped plants and observation of the production methods used.

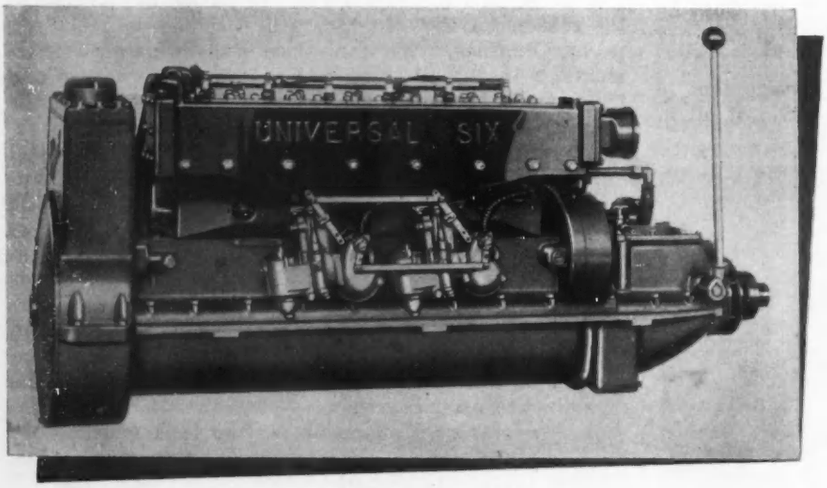


FIG. 1—UNIVERSAL SIX-CYLINDER 88-HP. MARINE ENGINE

The Exhaust Manifold Is Completely Water-Jacketed To Prevent Uneven Expansion and Contraction, and Ample Space Is Provided between the Cylinders for Adequate Cooling and To Avoid Clogging of the Water Passages by Salt Deposits. Valve Stems and Spark-Plugs Are Well Water-Cooled To Prevent Overheating under Full-Load Service Required of the Marine Engine

A MARINE engine is required to work virtually at full load all of the time during operating periods, whereas an automobile engine operates at full load only a small portion of the time. The average driver seldom works his car engine at full load and then only for a brief period. He drives a new car slowly for the first few hundred miles to break in the engine, but that same driver will open wide the throttle of his boat engine as soon as his new boat is clear of the dock.

Driving a car through deep sand may be regarded as analogous to the every-day work required of a marine engine. Those who have fought sand know the terrific strain imposed on the engine and on the entire car. A marine engine is built for heavy, continuous service, whereas a car engine is built for intermittent service. So, in general, a reasonable assumption is that the former is better for marine use, the car engine is better for propelling an automobile, and an airplane engine is superior to any other type for driving planes.

An automobile engine is designed primarily to operate on an even keel, but a boat engine operates at an angle, which in some cases may be as much as 15 deg.

[1] General sales manager, Universal Motor Co., Oshkosh, Wis.

The location of the oil-pump in the automobile engine may be such that a change is necessary so that it will function satisfactorily when installed at an angle. Other optional changes may result in a makeshift job; for example, it may be necessary to use a long suction tube in the base, which may not permit cold oil to reach the pump quickly enough to provide circulation.

Installation and Operating Considerations

The marine engine designed for operating at an angle has the water-jacket designed in such a way as to prevent steam pockets in both the cylinder-block and the head. The car engine is designed without consideration of marine service and so may have hot-spots in the cylinder-block or the cylinder-head or possibly both, resulting in poor efficiency and sometimes in cracked heads and blocks.

Placing the carbureter at an angle is easy and is usually taken care of as well in converted jobs as in marine engines. However, difficulty is likely to be experienced in providing a satisfactory drive for the gear-type water-pump. This may result in a makeshift job or necessitate operating at too high a speed, which causes undue wear on the gears and necessitates frequent replacing of the gears.

The design of the cylinder-block and cylinder-head of the marine engine differs from that of the car engine also in that greater space is provided between the cylinders to afford better cooling and also to prevent clogging of the passages by salt deposits. Valve stems and spark-plugs have more water-jacket space provided to prevent overheating under full-load service required of the marine engine. Correct distribution of water in the block and head is very important in the design of marine engines, and, since the coming of higher-speed and higher-compression engines, this factor requires greater attention. Some modern marine engines have a water-distribution plate into which the water first enters and is then carried by numerous brass tubes, which are sweated onto the distribution plate, to the most advantageous locations in the block to effect even and adequate cooling.

Cooling of the exhaust manifold also is an important consideration, for it is necessary to water-jacket the manifold for satisfactory marine service, hence marine engines usually are designed to provide complete water-jacketing of the exhaust manifold to prevent uneven expansion and contraction. (See Fig. 1.)

Converted motor-vehicle engines also have a water-jacketed manifold but, as the engine was not originally designed with this thought in mind, bolting the manifold directly to the block is not always possible; consequently, ears without a water-jacket are used to carry the hot exhaust gases from the block to the manifold and uneven expansion and contraction are almost certain to occur, resulting in blown gaskets and sometimes cracked manifolds. This condition causes little concern in four-cylinder engines but shows up in

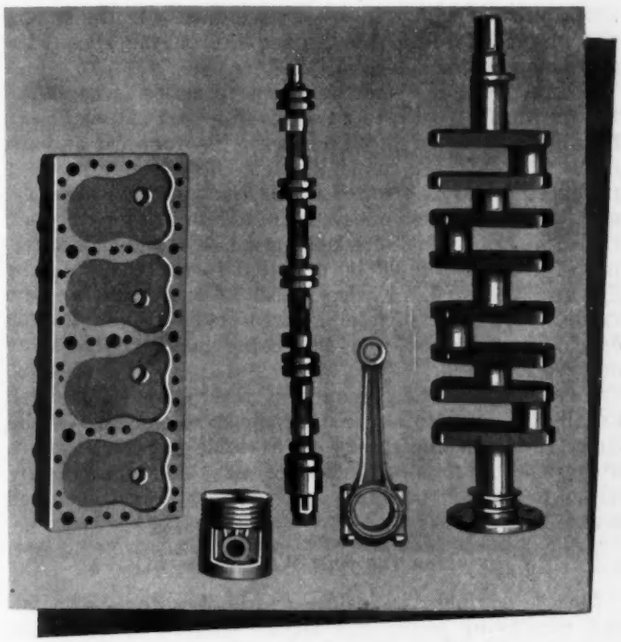


FIG. 3—PARTS OF BLUE JACKET ENGINE
Note Large Main Bearings at Both Ends of the Crankshaft

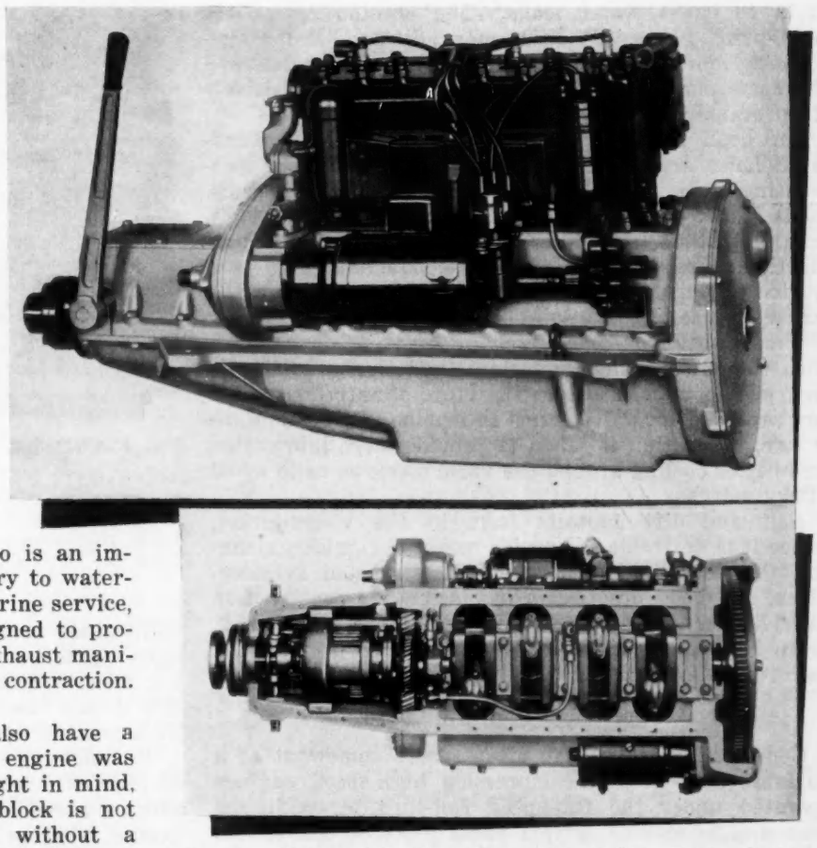


FIG. 2—MODEL AB FOUR-CYLINDER 47-HP. BLUE JACKET MARINE ENGINE
Note That the Flywheel Is Mounted at the Forward End and the Reversing Gear at the Rear End, According to Conventional Marine-Engine Practice, Necessitating Large Main Crankshaft Bearings at Both Ends. All the Mechanism Is Accessible When the Cylinder-Block and Upper Half of the Crankcase, as Shown Below, Is Lifted from the Base, Which Remains Bolted to the Engine Bed

sixes and especially in straight eights, for the longer the manifold is and the higher the engine speed, the more aggravated the condition becomes.

The conventional marine-engine practice is to mount the flywheel forward and the reverse gear aft, as shown in Figs. 2 and 3; therefore, both the forward and aft main bearings are made large. The car engine does not need a large front bearing, as both the flywheel and the transmission are mounted on the rear end; therefore, to adapt such an engine to marine practice, the reverse gear must be mounted in the rear and the flywheel forward, or vice versa. In either case the front bearing must take a greater load than it was originally designed for, and consequently early wear may be expected.

To withstand the demands of marine service, which usually calls for full operating speed 95 per cent of the time, it is also necessary to exercise greater care in fitting the bearings. Piston fits must be made slightly looser to prevent sticking, and possibly breaking under severe service.

Provisions for Salt-Water Operation

Marine engines are designed for salt-water operation, and core-print plugs are either eliminated or brass plugs are used; whereas, in making castings for automobile engines, the use of steel plugs is common practice. These plugs rust, eat away, and are almost certain to cause water leaks. The elimination of the core-print plugs, although more difficult and consequently more expensive, is the better practice followed by some marine-engine manufacturers so as positively to prevent core-print-plug leaks.

In good marine-engine practice the cylinder-head-stud holes are drilled and tapped blind, thereby preventing water leaks and corrosion around the studs. This is not common practice with automobile engines, as this method is too slow and expensive for mass production. Consequently, cylinder-head studs in a converted motor-vehicle engine will rust and eventually cause trouble.

Condensation is more likely to occur in marine service than in automobile service, and this condition is aggravated by salt water; therefore slightly looser fits are provided for valve stems in marine engines and, as a rule, precaution is taken to provide more lubrication and better cooling around the valve stems so as to avoid sticky valves.

Salt and dirt deposits form in the water-jacket, hence it is desirable to provide means for quickly cleaning the deposits out of the water-jacketed cylinder-block, and good practice in marine-engine construction provides an inspection plate on one side of the block, as in Fig. 4. In a few cases this is also provided on motor-car engines.

Compression and Oil Leaks

Compression leaks have always been somewhat of a nuisance and, in high-compression high-speed engines operated under the full-speed full-throttle conditions necessary in marine service, these leaks become a real problem. They are not of vital concern in the automobile engine, not only because of the intermittent-load service, but also because the driver usually can loaf into a service station and have the trouble quickly corrected. But how different the situation becomes when the engine is used in marine service; the severe work results in much more frequent leaks, and one may be miles from shore when the trouble occurs.

High-compression high-speed marine engines as well as converted engines have had plenty of compression-leak trouble. In this particular situation the converter is helpless, for the car-engine manufacturer could scarcely afford to use more expensive construction for the sake of the few sales made to the converter. On the other hand, the marine-engine manufacturer can, and some have, corrected the trouble permanently by changing the design and using an extra-large number of studs around each cylinder. One small high-speed marine engine having a bore of only 3 in. has

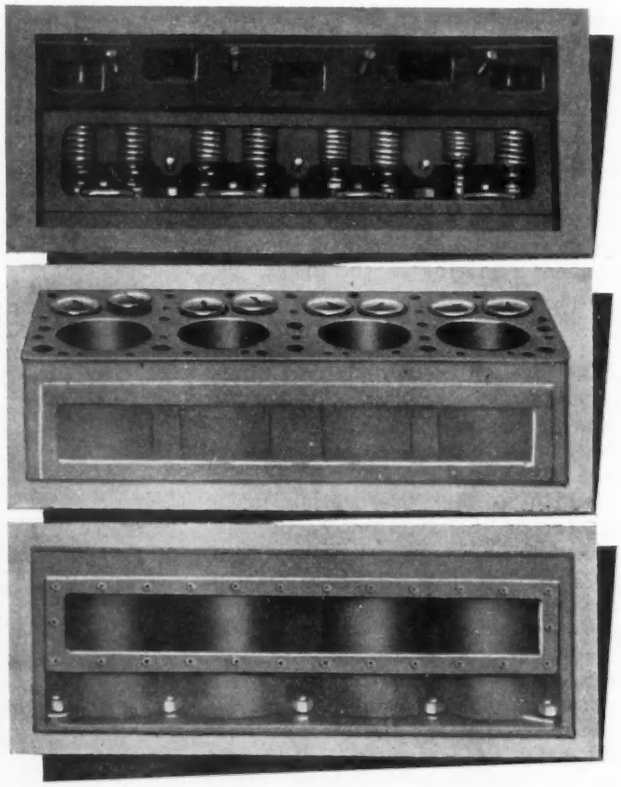


FIG. 4—CYLINDER-BLOCK AND VALVE-ARRANGEMENT OF FOUR-CYLINDER MARINE ENGINE

Access to the Valve Mechanism Is Easy and the Tappet Guides Are Removable. Extra-Large Silchrome Valves Are Used and a Large Inspection Plate Is Provided in the Side of the Cylinder-Block for Quickly Cleaning Out Deposits of Salt and Dirt in the Water-Jacket

eight studs around each cylinder; whereas usual automobile practice is to use not more than six studs even for much larger bores. Some marine-engine builders also divide the cylinder-head into two or more parts. This practice is usually followed in the large engines.

To build the car engine with the idea of making it oil-tight is not so important, and one has only to drive along a paved highway to appreciate the fact that the engine is prone to leak oil. In a boat, however, oil leaks are so objectionable that in recent years many marine-engine manufacturers have taken extreme care to prevent them. For example, in many modern marine engines all holes going into oil pockets are drilled and tapped blind. This is expensive and cannot ordinarily be tolerated in mass production. Other ex-

amples are the use on marine engines of heavier valve cover-plates, with provisions for extremely tight fits and a greater number of bolts to fasten the block to the crankcase and the base to the crankcase. These parts are also frequently doweled as a further precaution against leaks.

Engine Accessibility in Car and Boat

A motor-car engine designed for maximum accessibility in a chassis could easily be the most inaccessible piece of machinery when installed in a boat, for the method of getting at the engine is entirely different in a boat than in a car. Dropping the base of the engine in a car is a very convenient method of getting at the bearings and oil-pump, removing the pistons and so on; but, if installed in a boat, the same engine would have to be removed from the engine bed and most likely from the boat to do the same work.

But marine engines, with the exception of the very small, light ones, usually are designed so that ordinary repairs can be made without removing them from the bed. The large marine engines usually are provided with sufficiently large handhole plates in the side of the crankcase, and the cylinder-block is cast separately from the crankcase to afford accessibility. Also, in the smaller marine engines, where room is not available for large handhole plates, the cylinder-block usually is cast separately from the crankcase, thereby making it possible to change piston-rings or pistons without removing the engine from its bed.

Split-crankcase construction is exceedingly valuable in either an automobile or a marine engine from the standpoint of service cost. Such construction is considerably more expensive than the monoblock construction, which undoubtedly accounts for the fact that only a few of the higher-priced cars use split-crankcase construction. Few, if any, of the more expensive automobile engines having split-crankcase construction are used by any of the companies converting car engines for marine use.

Other examples of accessible features that usually are found in the modern marine engine, but which are not provided for in the converted engine, are the split flywheel-housing, permitting removal of the oil base without taking off the flywheel, provisions for removing tappets through the valve compartment and accessibility of the oil-pump.

Large Variety of Marine Engines

We have a large variety of types of marine engine, such as runabout, cruiser, fishing-boat and work-boat models and what not. To have so many different types for an industry that absorbs such a comparatively small number of engines may seem uneconomical, but seems essential to obtain the desired results.

The runabout boat requires a light-weight high-speed engine. Although low-speed performance is desirable, it is not essential, so the marine engineer has the opportunity to design his engines expressly for high-speed full-throttle operation, whereas the automobile engineer, designing only for car service, is limited by production cost and also must compromise in compression ratio, size of manifold, cam design, flywheel weight and so on to provide good slow-speed performance. The runabout marine engine has a further advantage in weight, as it can be made lighter by using aluminum for the crankcase, a procedure that is impossible in the conventional monoblock construction used in the car engine.

The other extreme is the work boat or heavy cruiser, which can be powered more economically with a slow-turning engine driving a large propeller. For example, assume 700 to 800 r.p.m. to be the most economical propeller speed. Here again the car engine is at a disadvantage because it was not designed to work at full throttle at such a low speed.

So we have a wide variety of operating requirements in the marine field. The marine-engine builder can take care of a considerable variety with one engine-design by making it into several models by the use of different heads, camshafts, manifolds, carbureters, valve-settings and so forth. The converter of automobile engines has the same privilege but, with a few possible exceptions, this is not done and it is surely not common practice.

A few companies have also been able to take care of a wide variety of operating conditions with one engine by developing silent reduction drives and supplying these in different ratios. For example, assume that we have a marine engine that is made in two models, one a high-speed engine to develop say 75 hp. at 3000 r.p.m., and the other a medium-speed engine to develop from 35 to 55 hp. in a speed range of 1200 to 2000 r.p.m. With these two models, plus two or three reduction-ratios, a great variety of exacting requirements can be taken care of by the one design.

The marine engine is subjected to terrific thrusts. When the boat is riding a storm, the propeller is out of the water one moment, with the engine racing madly; the next moment the boat drops off the wave and the propeller is thrust back into the water, throwing a terrific strain and thrust on the engine. For this reason, marine engines are provided with numerous holddown bolts, seldom less than six even in small sizes, and usually eight or more; whereas many converted car engines are installed on only four supports, and in many cases the size of the bolts is inadequate to take the terrific thrust, which causes these bolts to weave in the wood bed and finally become so loose that the engine must be reinstalled.

A correct twin-screw installation requires one true right-hand and one true left-hand engine; and, since automobile engines are not made in both true rights and lefts, converted engines cannot be used if one desires a correct twin-screw installation. Some compromises have been tried by reversing the block on one engine, but this is so obviously a makeshift that few builders care to make such installations.

Marine engines get many more years of service than do automobile engines, and marine-engine builders provide service parts almost indefinitely. The average life of a car engine is six years, and after a model is changed or discontinued the obtaining of service parts becomes very difficult after a few years. Therefore, if for no other reason than this, the second-hand value of a marine engine should be considerably greater than that of a converted car engine.

Marine-Engine Production Facilities

Exponents of converted motor-car engines have argued that marine-engine production is not large enough to justify equipping a factory with the necessary machinery for quality production. This is un-

(*Concluded on p.* 446)

The Automobile-Type Engine for Marine Service

Motorboat Meeting Paper

By H. E. Fromm[1]

THE SUCCESS attained by marine engines as built by the manufacturer of motor-vehicle engines clearly proves that such engines are entirely suitable for marine service provided rugged automobile, truck or motorcoach engines are used as a basis. However, this involves the necessity of applying the principles of marine design and practices. The author describes and illustrates such an engine developed and built by a leading motor-car-engine manufacturing company.

This makes possible the use of cylinder blocks, crankshafts, pistons, valves, tappets and many other minor parts used in the motor-vehicle engines.

The outstanding advantage is the use of modern methods of production, equipment, quantity purchasing and the financial resources of the automobile industry.

MANUFACTURERS of motor-vehicles long ago realized that, to bring the automobile to any degree of perfection, some manufacturing methods not previously devised or conceived would be necessary if automobiles were ever to come within the reach of all classes of the American people. The answer was mass production.

Mass production and standardization, as practised by the automotive industry, proved so successful that it was adopted by manufacturers of many other products. Ten or more years ago, when boat builders conceived the idea of following this trend, their problems were many. First, it was necessary to create a market for these boats, and many yachtsmen were prejudiced against the so-called stock boat. The general impression was that these boats were built with the idea of cheapness only and that inferior materials were used. Unfortunately, it was true that some of the earlier standardized boats were very poorly designed. This greatly retarded the progress of the standardized-boat builder. However, conditions began to change; labor and materials were advancing in price and the cost of small custom-built boats increased considerably. This gave the standardized-boat builders, with their methods of mass production and quantity buying, an opportunity to sell boats of good design and construction at prices far below those of custom-built jobs.

Competition made it necessary for each builder to constantly improve his product. More boat speed and smoother engine operation were demanded, necessitating powerplants of less weight per brake horsepower, with higher speeds and of better quality and selling at lower prices than the powerplants then available. Exclusive manufacturers of marine engines, whose methods of manufacturing were limited by their comparatively small production, could not afford to invest in the necessary expensive tools and equipment to produce marine engines at a price and of a quality to meet the requirements of this advancing industry.

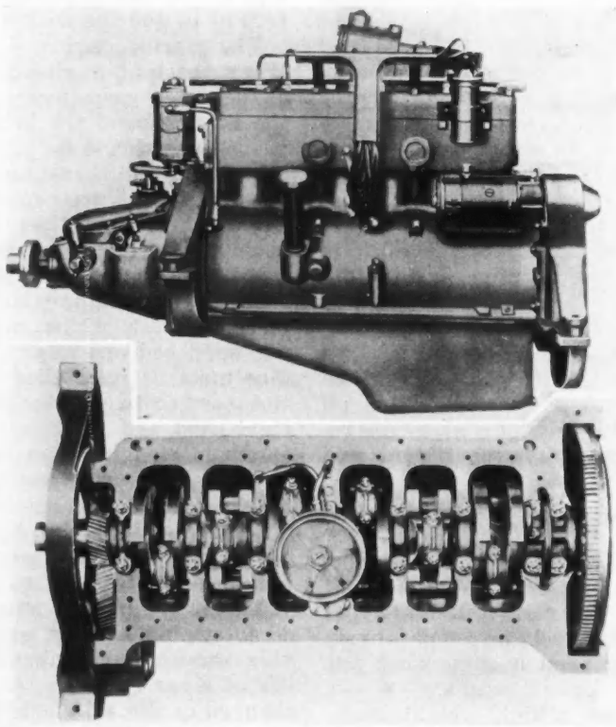


FIG. 1—A POPULAR TYPE OF MARINE ENGINE DEVELOPED AND BUILT BY A MOTOR-VEHICLE MANUFACTURER

The Lower View Shows the Method of Mounting the Counterbalanced Crankshaft and also the Helical-Gear Drive to the Water-Pump and Generator Driveshaft

Ruggedness a Prime Essential

The motor-car-engine manufacturers were then appealed to for assistance. Automobile engines were not at first looked upon very favorably, for this type of engine had been used in boats in the past to a small extent with very little success. They suffered because of small bearings, usually three on a six-cylinder engine; small crankshaft; splash-feed oiling system; and undersize piston-pins, and in general were not sufficiently rugged for marine service. A large percentage of these installations were made by amateurs. Their thought was

[1] Marine engine division, Amplex Mfg. Co., Detroit.

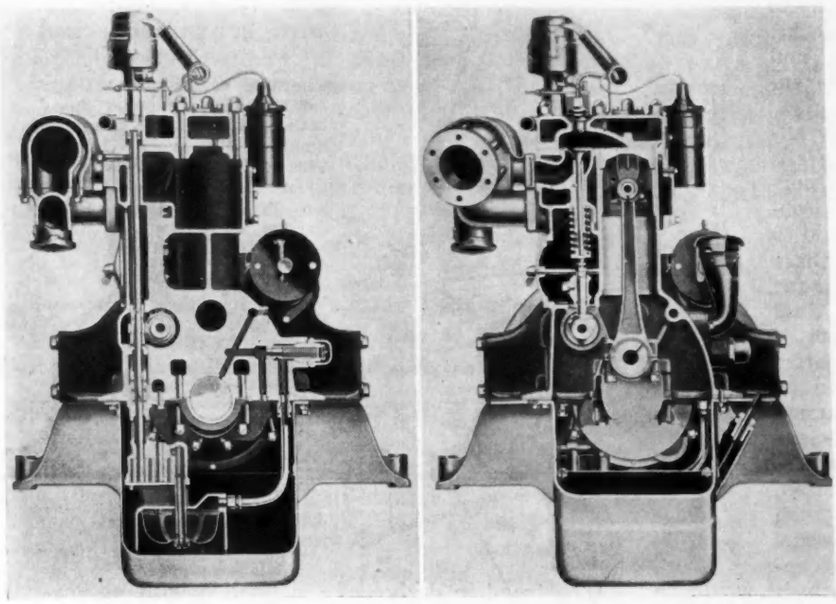


FIG. 2—CROSS-SECTIONS OF MARINE ENGINE THROUGH MAIN BEARING AND THROUGH CYLINDER AND CRANKPIN

that it was necessary only to add a reverse gear, a water-jacketed manifold, a water pump and a few other parts to obtain a successful marine engine. However, this did not prove true.

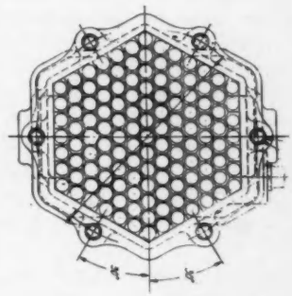
Marine engines were quite rugged compared with the earlier motor-car engines, having larger crankshafts, bearings between all cylinders and force-feed lubrication, giving long life with low cost of upkeep.

However, the ever-increasing demand for better performance combined with ruggedness had its reaction and no time was lost in meeting this demand. The motor-vehicle engine manufacturer, with his vast resources and engineering facilities, was able to develop and produce engines that were far superior to and more rugged than those ever before used by any industry, including the marine. These engines are cast in block with heavy cross-web construction providing supports for main bearings between all cylinders, full-pressure-feed lubrication on all bearings including the camshaft bearings, all counterweighted crankshafts and many other well-known features. These engines are used in many motorcoaches and trucks, which call for unusually severe service. Their general characteristics are identical with those of the engines used for marine service.

It is not possible, however, to take from the assembly line an automobile, truck or tractor engine built with piston, valve-stem and bearing clearances that are unsuitable for marine use and assemble it with a reverse gear and clutch purchased from one vendor, a water-pump from another, an oil-cooler from still another, and have a quality or satisfactory marine product. This is somewhat in the same category as was the assembled automobile of some years ago which has almost passed into oblivion.

Division of profits with divided responsibility for the various units, as well as the lack of opportunity to control the manufacturing of the various parts, does not form a very healthy background for any industry.

Less than four years ago, one of the largest and best-known car-engine manufacturers entered the marine engine field and within this short period has become not only one of the largest manufacturers of marine engines but the actual leader in the industry. This company was already in production on several very rugged automobile, truck and motorcoach engines. These were used as the basis for a



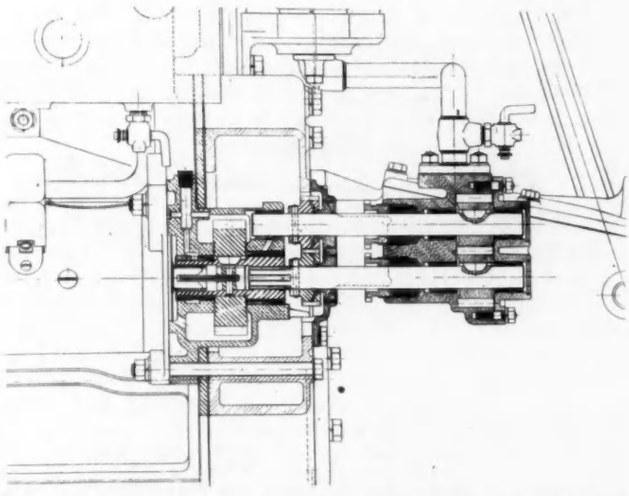


FIG. 3—WATER-PUMP, WITH DOUBLE DRIVESHAFT AND INDEPENDENT DRIVE-GEARS

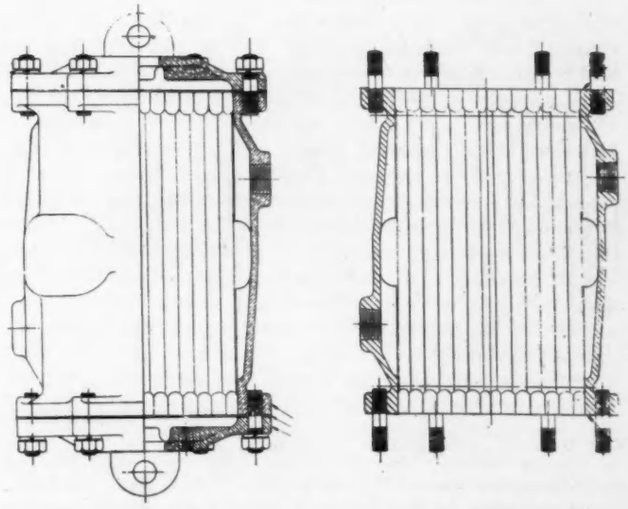


FIG. 4—TUBULAR WATER-COOLED OIL-COOLER

marine engine designed in such a way as to make possible the use of raw cylinder-blocks, crankshafts, pistons, valves, tappets and other minor parts of the motor-vehicle engines.

One can readily understand the many advantages gained from such a set-up. First, a decided advantage is gained through purchasing in large volume, which would probably be on the basis of approximately 200 to 300 sets of parts per day, whereas, if these same parts were intended and purchased for marine-engine production only, the total probably would not exceed 15 to 20 sets of parts per day. Secondly, all the automotive tool equipment, fixtures and jigs could be utilized for marine-engine manufacturing. Those who are not familiar with the extent of this equipment, which is absolutely necessary for quantity and quality production, doubtless will be surprised to learn that such equipment for the building of only one model engine would involve an expenditure of approximately $1,250,000. Such an investment would be beyond the possibility of anyone for the production of a small quantity of marine engines. This shows conclusively that the motor-vehicle engine manufacturer is the logical builder of small marine engines.

The question might be asked, Why not do with less equipment? This could be done but only at a sacrifice of low cost and good quality.

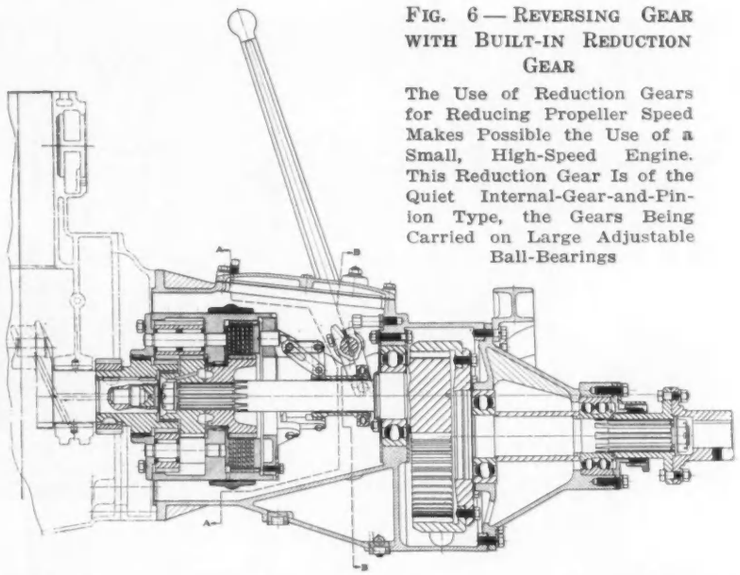


FIG. 6 — REVERSING GEAR WITH BUILT-IN REDUCTION GEAR

The Use of Reduction Gears for Reducing Propeller Speed Makes Possible the Use of a Small, High-Speed Engine. This Reduction Gear Is of the Quiet Internal-Gear-and-Pinion Type, the Gears Being Carried on Large Adjustable Ball-Bearings

The trend in design of the small marine engine has changed somewhat in the last few years through motor-car influences. For instance, at one time virtually all marine engines had the crankshafts, reverse gears and thrust bearings bedded into the lower half or base, with handholes in the side of the engine frame or housing. In most small marine engines today, the automobile-engine practice of suspending the crankshafts in

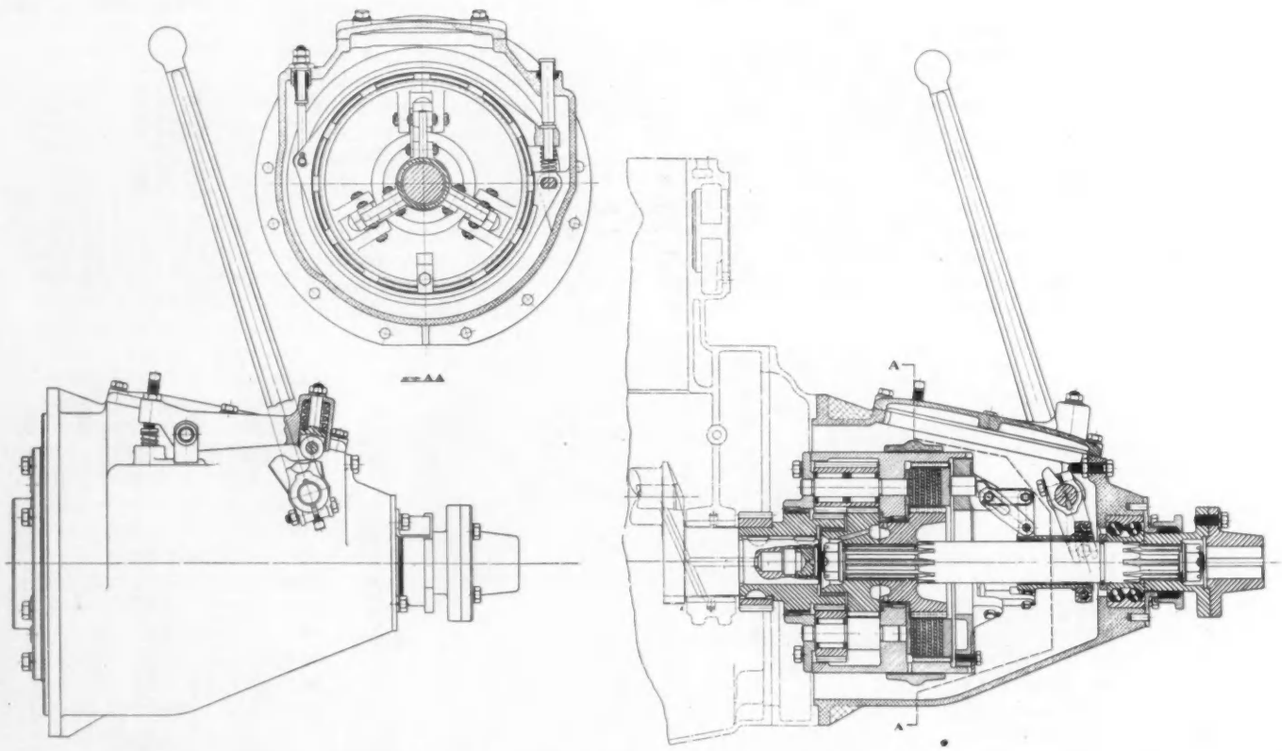


FIG. 5—REVERSING GEAR, BAND AND CLUTCH

This Gear Is Assembled in Its Base by Sliding the Case, with the Thrust Bearing, over the Clutch Shaft, then Fastening the End Plate and Splined Coupling in Place, Locking the Assembly, Which Can then Be Mounted as a Unit. A Noteworthy Feature Is the Use of Three Sets of Pinions Running on Roller-Bearings, Which Tends To Maintain the Alignment. Any Wear or Expansion of the Band Caused by Heat Is Compensated for by the Spring in the Rocker-Arm, Shown in the Drawing at the Left, Which Assures Reverse Action and Avoids the Necessity for Close Adjustment of the Band

the lower part of the cylinder block, making a more rugged construction, has been adopted. Handholes are being eliminated entirely, as these have been found useless for changing or replacing bearings. Examination has shown that, after once the present counterweighted crankshafts with bearings between all cylinders is assembled in the block, absolutely no opportunity is afforded to replace a bearing because of insufficient room to work. However, with large bearings and a good pressure-oiling system, the replacement of bearings is rarely necessary.

Successful Adaptations of Motor-Vehicle Engine

Engines of the motor-vehicle type undoubtedly are best suited for marine service. Let us consider one of these six-cylinder 3⅝ x 5-in. engines having the cylinder block and upper half of the crankcase cast integrally, as in Figs. 1 and 2, and made in metal-pattern equipment. This assures uniform thickness throughout. Water-jackets are provided with large clean-out holes. Oil passages are rifle-drilled to all bearings, including the camshaft bearings. This eliminates oil pipes and joints and difficulty from this source. The lower half of the cylinder block, with its girder-like construction and cross webs, supports the seven main bearings. The counterweighted, dynamically and statically balanced crankshaft of 2⅝-in. diameter is much larger than is used in the many so-called marine engines having a bore of 4½ to 5½ in. From this, one can readily see that, with the perfectly balanced light-weight reciprocating parts, the bearing pressures on the automobile-type engines are considerably less than on the so-called marine engines.

By light-weight reciprocating parts I mean the slotted-skirt invar-strut type of aluminum-alloy piston, which has less weight per square inch of cylinder area than any other piston yet devised. These pistons are rugged, will retain their concentricity and can be fitted with the same clearances as are used with cast-iron pistons.

Wide-faced helical spur gears are used instead of timing chains. The auxiliary-drive gear, that is, the water-pump and generator drive, is carried by the accessory-shaft bracket, which is piloted into the cylinder block or gearcase, with the generator bolted on the forward side. The generator drive is of the flat or laminated steel-spring type that eliminates shock. This device has been used successfully on motor-vehicle engines for some time. On the after end of this bracket is the water-pump drive and upper pump-shaft support bearing. All bearings in this bracket are drilled for force-feed lubrication.

The Water-Pump and Oil-Cooler

The water-pump is bolted to the after side of the gearcase cover and piloted into the accessory-shaft bracket, eliminating any possible chance of misalignment. The pump, which is of the gear type, has double driveshafts connected with independent drive-gears running in oil, as shown in Fig. 3. This prevents the bronze pump gears from making contact and prevents gear wear, as water in general is abrasive because of the silt and sand so often found in rivers and shallow lakes. The independent steel drive-gears are located inside the gearcase and run in oil at all times. To prevent oil leakage to the outside of the case, these gears have an oil thrower incorporated in the drive gears.

A tubular-type oil-cooler, shown in Fig. 4, is fitted with vertical tubes of suitable size to assure proper drainage of water when the engine is stored for the winter. The oil enters the lower end of the cooler, and the outlet is near the top, preventing any chance of the cooling tubes becoming air-bound and decreasing in efficiency. Collector pockets extend the full length on both inlet and outlet sides of the cooler, giving cross-flow for the oil through the full length of the cooler. To prevent the building up of excessive oil pressure when starting up with cold oil, due to resistance to flow through the tubes, a short oil passage is provided which gives the same advantage as a bypass valve without its disadvantages.

Removable covers on the water ends make possible the clearing of the tubes of any foreign matter taken in with the circulating water.

Oil is carried in the oil-pan or reservoir. A single oil-pump fastened to the cylinder block and submerged in oil provides engine lubrication. A deep oil-pan is furnished for engine installations at shaft angles up to 15 deg. and a shallow pan for shaft angles that do not exceed 8 deg. This method of providing lubrication was adopted in preference to the double-pump and dry-sump method, because of its simplicity and assurance of positive operation.

Reverse Gear and Clutch

The reverse gear and clutch, shown in Fig. 5, is mounted somewhat differently than that of the so-called marine engines. This gear is first assembled in the reverse-gear case by sliding the case with the thrust bearing over the clutch shaft. The end plate and splined coupling are then fastened in place, locking the assembly, which can then be mounted in one unit. As the bearing on the pinion plate is slightly larger than the outside of the crankshaft gear, this allows the pinion plate to slide over the gear. Three sets of pinions running on roller-bearings are noteworthy features uncommon to other reverse gears. The conventional practice is to use two sets of pinions, but this results in the gears tending to crawl out of alignment, whereas the use of three sets of pinions tends to maintain the alignment.

The clutch throw-out yoke is of the ball-bearing type instead of the customary bronze-horseshoe type.

One of the serious problems encountered with the ordinary reverse gear is the frequent and close adjustments necessary. Any slight wear or expansion of the reverse band from overheating will make reversing inoperative. These conditions have been overcome in this particular marine engine through the use of a patented reverse rocker-arm having a spring-loaded plunger that applies pressure to compress the reverse band. By this arrangement the tension of the spring, when compressed 1/16 to 3/32 in., provides sufficient pressure on the band. Any wear or expansion of the band due to heat is compensated for by the spring in the rocker-arm, assuring reverse action at all times. This not only avoids the necessity of close adjustment but acts as a safety device in case the adjustment should be screwed down too tightly. Under these conditions, the spring will be compressed further and prevent distortion of the lug on the reverse band.

Quiet reduction gears in connection with the smaller automotive-type engines make possible comparatively low propeller speeds with high-speed engines. An-

other outstanding advantage of the small reduction-gear engine is its lower price. One of these power-plants of equivalent horsepower and speed can be purchased at a considerable saving over a large-bore straight-drive engine. Furthermore, with this type of engine an appreciable saving in weight and greater fuel economy are realized.

The reduction gear is incorporated in the same case with the reverse gear, as in Fig. 6, and is of the internal-gear-and-pinion type, with adjustable centers necessary to obtain correct gear-setting. These gears are carried on large ball-bearings, and the reduction-gear case is jacketed for water circulation.

As the automotive manufacturers are gear specialists, they have done much to solve the reduction-gear problem. Their years of experience with gears of various types have proved that the internal gear not only gives longer life and more tooth contact but provides absolutely quiet performance.

Marine engines have always been built with little thought of easy installation. This neglect increased installation costs. Ordinarily, marine-engine supports extend the entire length of the engine parallel to the center line of the shaft. This is unnecessary, since four lugs are sufficient to bear the weight and torque of the engine. By placing the after two lugs slightly above the center line of the shaft and the two forward supports somewhat below the center line of the shaft, the engines can be installed directly upon the girders of the boat. This new method of installation entirely eliminates the bed logs and simplifies the alignment of engines.

With a product such as outlined, it is apparent that the motor-vehicle-engine manufacturer has contributed much toward the advancement of the standardized-boat-building industry. This is most gratifying to the boat builders, for their art is advancing with rapid strides and they appreciate the efforts of the engine manufacturers to keep pace and work in close cooperation with them.

Oil Cooling and Oil-Coolers

(*Concluded from p.* 437)

jected to a stiff shock, the temperatures would begin to drop. At the time we did not know just what caused this condition, but later found that it was due to the congealing of the oil on the tubes, thus insulating the oil in the metal tube from giving up its heat to the air blast. I think that the thinning out of the oil film to get the greatest heat-dissipation with the minimum material is one of the fine features of this cooler discussed today.

W. R. RAMSAUR:—I have no data with me concerning the heat-transmission coefficient of coolers, but I shall be glad to send them as soon as I get back to Lockport. Neither have I the figures on the oil velocity, but these can be calculated easily.

The oil-swept surface on the 178-tube unit was 320.4 sq. in.; on the 161-tube cooler it was 289.8 or 290; and on the 112-tube unit it was 102.6. The reason why the 161-tube cooler does not dissipate as much heat per tube as the 112-tube as compared with the 178-tube cooler is that on the medium cooler, because of its smaller size, we have not available the necessary length of oil-flow through the core. We find that a certain length-width ratio should be followed, and on the small cooler we were not able to do that.

The next question was concerning the oil warm-up in winter. The tests that I showed were made with an engine having a thermostat opening at 170 deg., and that is the reason we obtained the warm-up shown. However, on engines having no control of the water temperature by thermostats or shutters, we are not able to duplicate those temperatures with any great degree of accuracy.

Marine versus Converted Automobile-Engines

(*Concluded from p.* 441)

doubtedly true in some cases, but it is decidedly not true in modern marine-engine factories. If anyone doubts this statement, all that is necessary is to take a trip through one of the better-equipped factories and note the equipment and production methods used. Granted that modern facilities are not available in small marine-engine shops, these cases can be offset by citing the numerous individuals having only a small garage equipment who are converting car engines for boat service. The cost of converting is small compared with the cost of manufacturing. Almost any garage can go into the business, and go out just as easily, for only a small investment is at stake; but if, and when, it goes out of business each of the customers will have an orphan so far as the conversion parts are concerned.

In conclusion, let me ask why many converted automobile engines are called marine engines. If the converter believes that they are as good as marine engines, why does he not take advantage of the million-dollar advertising appropriations of the car manufacturers and call each engine by its right name? Converted engines should be labeled as such. The public has no way of knowing from some of the converters' literature or advertising that the engines are converted automobile engines, and many such engines are purchased in the belief that they are genuine marine engines.

The Use of Zinc and Zinc Alloys in the Automotive Industry

Annual Meeting Paper

By Robert M. Curts[1]

THE PURPOSE of the paper is to discuss zinc as an engineering material. To this end the author reviews briefly the part that zinc and its alloys have played in the past and discusses recent development in zinc-base alloys which have greatly enlarged their field of use in the automotive industry.

Among the various specific subjects treated by the author are brass, nickel and silver, rolled zinc and rolled zinc-alloys, zinc wire, extruded zinc shapes and die-castings. He states that in the early days of die-casting, alloys composed principally of tin or lead were used almost exclusively, but that castings made of these alloys did not possess the necessary strength and their use was greatly restricted. Zinc was tried and found to have certain advantages and, finally, a special zinc-alloy was adopted. Shortly after this the so-called high-grade zinc was introduced.

After discussing die-cast zinc-alloy gears, the author treats the subjects of zinc alloys for body hardware and other equipment, recent improvements in zinc alloys, and zinc data on the zinc-aluminum-alloy system. Heat-treatment of zinc-base die-casting alloys, water-vapor tests, the disastrous effects of contamination and the physical tests that can be applied to die-casting alloys are considered in some detail. The use of inserts in zinc-alloy die-castings, plating methods, cleaning and other procedures, the nickel-plating process, enameling, japanning and lacquering are touched upon.

In conclusion, the author summarizes his paper by stating that metallic zinc is used in the automotive industry for electro-galvanizing; as a constituent of brass; as rolled sheet and strip for a variety of fabricated parts of which running-board molding heads the list; and in the production of a great number of die-cast parts. The marked improvement in both rolled zinc-alloys and zinc die-casting alloys has done much to stimulate added interest in this white non-ferrous metal, the price and properties of which lend themselves well to effect economy without jeopardizing quality.

Not only have improvements been made in the physical properties of the various zinc-alloys, but the application of attractive and durable plated finishes can now be accomplished without difficulty, according to the author. The number of parts on the automobile which are made of zinc or zinc alloys is increasing annually. Additional investigations are being undertaken to produce still other zinc alloys of suitable properties for use in a wider range of automotive parts.

Among the major points considered in the discussion are included the maximum allowable stress in working particular metals, undesirable physical changes that occur at a temperature of 500 deg. fahr. and result in a decrease in strength, the purity of zinc and zinc-alloys, and further data on die-castings, including their use as bearing material.

THE automotive engineer has two primary and essential responsibilities: (*a*) to make possible the manufacture of better cars without materially increasing the cost thereof, and (*b*) to reproduce with greater economies the high standards of design and performance existing in the present-day product. Improvements must be made for the most part without adversely affecting the cost sheet. Paring costs by forcing down the price of raw materials or accessory parts used in assembly to the point where there is no legitimate profit to the supplier is certainly not a wholesome way to effect economies in motor-vehicle manufacture. Economies must come through the substitution of new manufacturing processes or by a better understanding of engineering materials which will result in the intelligent substitution of such materials as may show an economic advantage without cheaping the product.

My purpose in this paper is to discuss zinc as an engineering material. To this end I shall review briefly the part this metal and its alloys have played in the past, and will discuss recent developments in zinc-base alloys which have greatly enlarged their field of use in the automotive industry.

[1] M.S A.E.—Engineer, New Jersey Zinc Co., New York City.

Zinc-Base Alloys

Of special interest to the production engineer are the zinc-base alloys which have been developed for the rapid production of castings by the pressure die-casting method. Of equal interest to body and designing engineers are the improvements in plating and in finishing technique which give confidence in the use of zinc, particularly rolled zinc, for body moldings, trims, hub caps, radiator and gasoline-tank caps, running-board molding and many other parts. In addition to this greatly improved plating technique, the recent investigation of stronger rolled zinc-alloys likewise opens up new fields.

Zinc is the most economical of the non-ferrous materials. Starting with this fundamental advantage it has been possible to find alloys which, being essentially composed of zinc, are moderate in cost and yet have

many of the desired physical and rust-resistant properties of more expensive metals and alloys.

A few years ago the use of zinc in the automotive industry was limited (*a*) to the tonnage employed in the manufacture of brass for certain cast and fabricated parts, (*b*) to a relatively small consumption in electro-galvanizing, that is, electro-zincing of various steel parts to prevent rusting, and (*c*) to a fair consumption in the form of rolled zinc for meter cases, running-board moldings and door plates. But brass radiators and many other brass parts were replaced with plated ferrous materials. A wave of enthusiasm for cadmium-plating and parkerizing replaced a considerable quantity of the zinc used in electro-galvanizing; and there always has been a classical argument as to the advantages and disadvantages of zinc versus aluminum for running-board molding. Be that as it may, it certainly looked as though the consumption of zinc might become quite insignificant in the Country's largest industry.

Brass and Nickel Silver

A considerable quantity of brass and some nickel silver are still used by the automotive industry. Brass normally contains from 30 to 40 per cent of zinc, while nickel silver contains about 18 per cent. Since these alloys are copper-base rather than zinc-base alloys, they will not be discussed further.

Electro-Galvanizing

The protection of iron or steel parts by the electrodeposition of zinc on their surfaces is relatively an old art. For several years cadmium-plating and other rust-proofing methods have replaced electro-galvanizing to a considerable extent. It was found that certain patented rust-proofing processes afforded a very satisfactory surface for subsequent enameling or lacquering at reduced cost. The silvery-white appearance of cadmium-plate was thought to be more pleasing than the blue-gray of zinc; but, as cadmium is much more expensive than zinc, a stronger argument had to be introduced before it was generally adopted. This argument was based on its superior resistance to corrosion in the salt-spray test, the interpretation of which has caused much critical comment. Recently Dr. Gillett, editorial director of *Metals and Alloys*, published a rather comprehensive symposium[2] of many expert opinions on the relative protective value of zinc and cadmium on iron or steel. Among all these expert opinions I find only one as coming from an automotive engineer; namely, H. C. Mougey, of the research laboratory of the General Motors Corp. From his opinion, I quote as follows:

> In a few cases we have used cadmium-plating where the color obtained with cadmium was more attractive than the color obtained with zinc. However, our experience has made us believe that in actual service the same thickness of zinc is at least as good a protection as cadmium, and since cadmium is more expensive than zinc, it is also our belief that it is an economic mistake for us to use cadmium where we are not required to use it from the standpoint of appearance.

In the same symposium C. D. Hocker, of the Bell Telephone Laboratories, says:

> On two occasions we have made comparisons of cadmium-plating and zinc-plating in actual outdoor tests . . . . In both instances, when exposed on the roof of our building at 463 West Street, New York City, the cadmium-plated samples rusted more quickly than the zinc-coated ones.

Actually, the amount of zinc involved, should it be used exclusively, would be a very small fraction of the total used in other forms. The foregoing discussion is included only because I am so often questioned as to the relative merits of cadmium versus zinc-plating.

Rolled Zinc and Rolled Zinc Alloys

Until rather recently rolled zinc was available only in the form of unalloyed strip and sheet having a relatively low tensile-strength, from 18,000 lb. per sq. in. for soft-temper grade to 35,000 lb. per sq. in. for hard-temper grade. Besides having a relatively low tensile-strength as compared with brass and other materials which it might economically replace, unalloyed rolled zinc is practically self-annealing at normal temperatures and has a tendency to creep or take a permanent set when subjected to sustained loads.

The zinc industry soon recognized that, if zinc in the rolled form was to enjoy a more extensive application in the automotive industry, alloys must be produced which could be commercially rolled and which, at the same time, would have physical properties quite similar to those obtainable in brass and other commonly used rolled alloys. Further, a suitable plating process must be made available so that the use of such alloys as were developed could be extended into fields where reliable plated finishes were the essential factor. Much work has been done in the development of new rolled-zinc alloys, and, although these alloys are still somewhat in the experimental stage, they promise to be a definite contribution in effecting economies in the automotive industry.

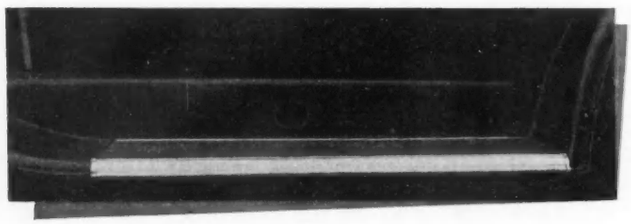


FIG. 1—CHROMIUM-PLATED ZINC RUNNING-BOARD MOLDING APPLIED TO A TEST CAR

After 11,000 Miles of Service over a Period of Nine Months, a Careful Examination Revealed No Failure of the Plated Coating. The Usual Scratching and Scuffing Produced no Evidence of Flaking or Corrosion. This Molding Was Finished with a 25-Min. Nickel-Plate, Followed by about 3 to 5 Min. in the Regular Chromium-Plating Bath. Chromium-Plated Zinc-Moldings Are Standard Equipment on a Number of 1931 Models

Simultaneously with the development of new alloys for rolling, a careful study was made of the various existing plating procedures. As a result of much careful experimentation, a plating technique has been recommended[3] which results in the deposition of tough, dense, adherent coatings on zinc or zinc-alloy surfaces.

This latter development has been the greatest contributing factor in new applications of ordinary commercial rolled zinc which is perfectly satisfactory from a strength standpoint for cowl, for drip and for splash-

[2] See Correlated Abstracts; Metals and Alloys, August, 1930.

[3] See Plating of Rolled Zinc and Zinc-Base Die-Castings; New Jersey Zinc Co. Research Division.

guard moldings, trunk-rack and gasoline-tank trim, gasoline-tank and radiator caps, escutcheons, switch plates, flexible cables, dome lamps, ash receivers, engraved instrument-panels and running-board moldings. (See Figs 1 to 3.)

Ordinary rolled zinc has been used for many years for running-board moldings. Unlike plated steel, it will stand considerable abuse without serious corrosion. However, it is subject to tarnishing unless protected by lacquer, the protective effect of which is quite limited with respect to time. Before the advent of chromium-plate, the tarnished zinc molding was not a serious problem but, with the introduction of a bright and relatively non-tarnishing chromium-plated finish on the lamps, bumpers, outside hardware, cowl molding and, in some cases, the windshield, the dull zinc and aluminum moldings received more critical consideration. Within the last year, a number of the large engineering laboratories have satisfied themselves that the claims made for chromium-plated zinc are well founded and several manufacturers have specified it for their 1931 models.

Tests made in the Chrysler engineering laboratories[4] on commercially plated zinc running-board molding showed that, after 70 hr. of continuous exposure to the salt spray, the surface was as good as when received from the factory. This test in itself does not mean very much, but it indicates that a continuous plate of chromium can be applied to zinc if the right procedure is followed. Further, it is comforting to those who still believe that the salt-spray test has some definite merit, the standard requirement of which test being that the plated coating shall successfully withstand a test of anywhere from 16 to 30 hr. without evidence of failure.

[4] Data not yet published.

Of greater importance is the practical service-test conducted by the same laboratory. A set of chromium-plated moldings was installed on one of the service cars. After eight months' continuous use, the molding was examined and pronounced in excellent condition. The research division of the New Jersey Zinc Co. likewise installed several sets of molding on company cars. After 11,000 miles, representing nine months of use, the moldings were carefully inspected and no evidence of flaking or excessive corrosion could be seen. Except for scratches caused by hobbed-nail shoes and the like, the moldings possessed the same bright appearance as when installed. I could cite many other tests which substantiate the belief that it is now possible to apply a very satisfactory nickel or chromium-plate to rolled-zinc parts.

Zinc Wire

There has been an appreciable increase in the production of zinc wire for use in the manufacture of brake-linings. The substitution of zinc for brass wire is said to cut down the scoring of the brake-drum and increase the general braking efficiency.

Extruded Zinc Shapes

Ductile, relatively soft, extruded zinc-shapes have recently been made available for drip and body molding. Here again the ease with which tough, adherent plated-coatings can be applied to such shapes probably will make its availability of special interest to body engineers. Zinc has the distinct advantage of being a white non-rusting base; so, in the event of a scratched or worn plate, no great contrast is evident. Any car owner who polishes the plated parts of his car vigorously enough to wear away the chromium-nickel film probably would keep any exposed zinc areas polished to a degree which would make them hard to find.

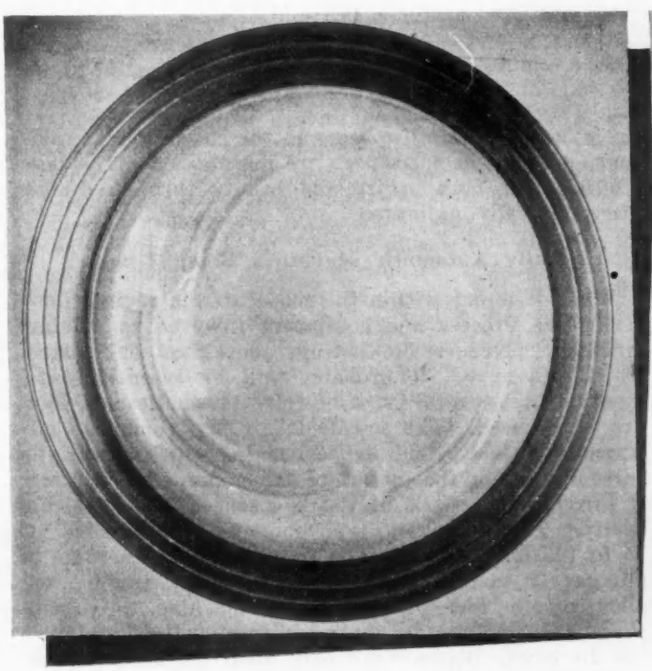


FIG. 2—DOME-LIGHT RIM FABRICATED OF ROLLED ZINC
This Rim Is Finished in "Butler Silver," Which Consists of a Nickel-Plate Subsequently Brushed with a Fine Abrasive Compound

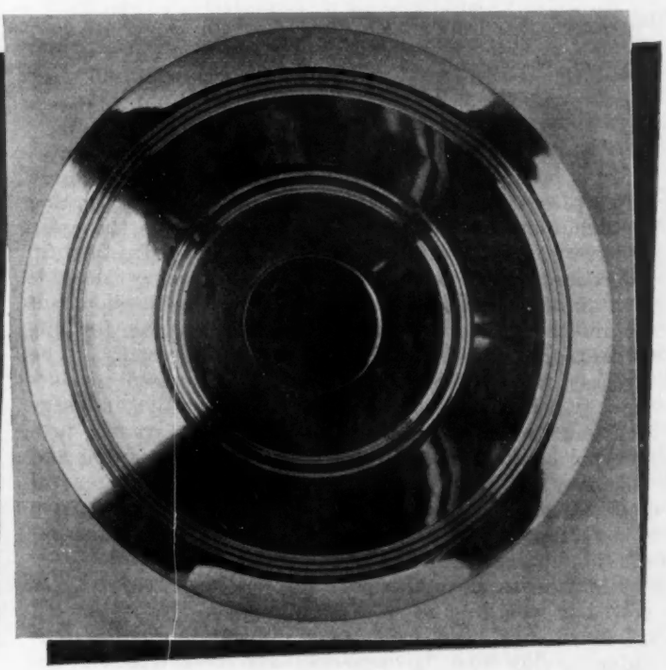


FIG. 3—WIRE WHEEL HUB CAP CONSISTING OF A THIN NON-FERROUS METAL SHELL REINFORCED BY A CADMIUM-PLATED STEEL BASE
The Shell Is Processed of Rolled Zinc and Is Finished in Chromium-Plate

FIG. 4—INTERIOR OF THE DIE-CASTING PLANT OF THE A C SPARK PLUG CO.

A Battery of Machines Engaged in the Production of Fuel-Pump Bodies, Speedometer Frames, Instrument Panels, Carbureter and Other Parts Is Shown. The Machines Are Motor Driven and Are Completely Automatic. Pressures Approximating 1000 Lb. per Sq. In. Are Utilized To Force the Molten Zinc-Alloy into the Cavities of the Water-Cooled Dies Where, in a Few Seconds, It Is Solidified and Ready for Trimming

Die-Castings

In a broad sense, the term "die-casting" may be applied to castings made either by pouring or by forcing molten metals into dies. (See Fig. 4.) To the automotive engineer, die-casting means the swift, faithful reproduction of intricate parts by forcing suitable molten alloys into water-cooled dies. The development of die-casting equipment and of alloys suitable for this process has been rapid and most interesting. The process itself is well adapted for high-speed production, which is one reason why the automotive industry consumes a large percentage of the total yearly production of zinc-base-alloy die-castings. The speed and efficiency of this process, together with the general economies effected through the use of less expensive non-ferrous alloys, are directly responsible for the reduction in cost of many parts on the automobile.

Limitations as to size have not yet been reached. A cowl bar weighing 14 lb. and having an over-all length of 41 in. has been made in a duplex die-casting machine having two "goosenecks" and two separate entrances at opposite ends of the die. Accuracy may be had to ± 0.002 in. per in. up to 3 in., with ± 0.001 in. per in. of additional length. A draft of 0.002 in. per in. is desirable on all cores. In the case of some castings, even closer tolerances are maintained. The possibilities for both utility and beauty through design are practically unlimited.

Fully Automatic Machines Being Used

While it is not within the scope of this paper to describe the process and equipment involved in making zinc-alloy pressure die-castings, hereafter designated as "die-castings," it probably will be interesting to mention that several types of fully automatic machines are being used. The so-called "air" type employs air pressure at 250 to 500 lb. per sq. in., which exerts its force directly on the surface of the molten alloy, forcing it through the nozzle of the "gooseneck" into the die cavity. The "plunger" type employs air pressure at 75 to 125 lb. per sq. in., the forces of which actuate a plunger or piston which, in turn, forces the molten alloy into the die. In this type of machine, the actual pressure which may be applied in forcing the metal into the die cavity depends not only upon the air pressure but also upon the relationship between the size of the piston in the air cylinder and the size of the plunger in the metal container. For those who are interested in a detailed description of the process and equipment, I recommend Marc Stern's recent book[5].

[5] See Die-Casting Practice, by Marc Stern; McGraw-Hill Book Co., Inc., 1930.

Special Zinc Alloy Adopted

In the early days of die-casting, alloys composed primarily of tin or lead were employed almost exclusively. But castings made of these alloys did not possess the necessary strength and their use was greatly restricted. Zinc was tried and found to have certain advantages. But unalloyed zinc was not suitable because it had a relatively low tensile-strength of 14,000 lb. per sq. in. and also because it showed a distinct tendency to dissolve the iron or steel parts of the die-casting machine with which it came into contact.

After considerable experimentation, an alloy containing about 6 per cent of tin, 0.5 per cent of aluminum, 2.75 per cent of copper and the balance of prime western zinc, as shown in Table 1, was adopted. This alloy, having a tensile-strength of 20,000 to 21,000 lb. per sq. in., was still relatively weak and its use was restricted to the production of small and unimportant castings. Additional investigations involving the study of the aluminum-copper-zinc alloy-system resulted in the so-called "4-3" or "5-3" alloy containing 4 to 5 per cent of aluminum, 3 per cent of copper and the balance zinc; and the "12-3" alloy containing 12 per cent of aluminum, 3 per cent of copper and the balance zinc.

This type of alloy had much better initial physical properties; but, during the early history of their use, much difficulty was encountered because of certain aging phenomena which were not clearly understood at that time. This same instability was experienced in the aluminum-copper-tin-zinc alloys in 1914, and was reported by H. M. Williams[6].

A resumé of Mr. Williams' work in this connection is particularly interesting because the results of his findings did much to accelerate work on alloys which has culminated in the present availability of strong permanent zinc-base die-castings. Mr. Williams' problem originated in a complaint regarding type wheels used in the assembly of cash registers which had been exported to Cuba. They had been cast of an alloy containing about 1 per cent of aluminum, 5.5 per cent of copper, 7.5 per cent of tin and 86.0 per cent of low-grade zinc. Through exposure to the warm moist atmosphere of the semi-tropics they had undergone considerable change in dimensions, which impaired the proper functioning of the machines. The effect of this failure has had a marked influence in building up a certain reluctance on the part of some engineers to employ zinc-base die-castings today. They do not realize that there has been as much improvement in zinc alloys for die-casting since 1914 as there has been in the general design and production of the automobile.

TABLE 1—A.S.T.M. SPECIFICATION B 6-18 FOR SPELTER (ZINC)

	Impurities, Per Cent			
	Lead	Iron	Cadmium	Total, Max.
High Grade	0.07	0.03	0.07	0.10
Intermediate	0.20	0.03	0.50	0.50
Brass Special	0.60	0.03	0.50	1.00
Selected	0.80	0.04	0.75	1.20
Prime Western	1.60	0.08	...	...

[6] See Swelling of Zinc-Base Die-Castings; American Institute of Metals, 1917-1918.

[7] U. S. Patent No. 1,596,761, dated Aug. 17, 1926; New Jersey Zinc Co.

[8] U. S. Patent No. 1,779,525, dated Oct. 28, 1930; New Jersey Zinc Co.

[9] Maximum Pb+Cd+Sn=0.015 per cent.

TABLE 2—PROPERTIES OF A ZINC DIE-CASTING ALLOY COMPOSED OF 4 PER CENT OF ALUMINUM, 3 PER CENT OF COPPER, 0.05 TO 0.10 PER CENT OF MAGNESIUM AND THE BALANCE OF HORSE-HEAD SPECIAL ZINC

Specific Gravity	6.8
Melting Point, deg. cent.	393
Tensile Strength,[a] lb. per sq. in.	47,500
Elongation in 2 In., per cent	3.7 to 4.3
Impact Value, ft-lb. per sq. in.	In excess of 125
Compressive Strength, lb. per sq. in.	90,000
Brinell Hardness Number (10-mm. ball with 500-kg. load for 30 sec.)	85
Shore Scleroscope Hardness	33
Rockwell Hardness (red figures on *E* scale)	93
Specific Thermal Conductivity between 25 and 100 Deg. Cent., cal. per cc. per deg. cent.	0.253
Thermal Expansion per Unit Length, per deg.	
Between 25 and 100 Deg. Cent.	0.0000295
Between 77 and 212 Deg. Fahr.	0.0000164
Electrical Conductivity at 20 Deg. Cent. (68 Deg. Fahr.), mhos per cc.	136,277
Electrical resistance at 20 deg. cent. (68 deg. fahr.), ohms per cc.	0.000007338
Temperature Coefficient[b] between 20 and 100 Deg. Cent. (68 and 212 Deg. Fahr.)	0.003030

[a] Tensile strengths in excess of 47,500 lb. per sq. in. can be obtained under certain casting conditions.

[b] The temperature coefficient is used in the following formula for calculating resistance at temperatures other than 20 deg. cent. (68 deg. fahr.)

$$R_T = R_{20}\,(1+[\alpha(T-20)])$$

High-Grade Zinc Introduced

The introduction of high-grade zinc (see Table 1), such as Horse Head, as the base metal for the 4-3 and 5-3 type of alloy, resulted in a marked increase in stability. The reason for this is discussed herein under the heading, Disastrous Effects of Contamination. The next advance was made through the introduction of small quantities of magnesium, preferably about 0.1 per cent. This alloy[7] is known under the registered trade-mark as Zamak No. 1, or the "4-3-0.1" alloy. By careful limitation of the impurities in the zinc, the magnesium content can be reduced safely to 0.05 per cent, as for Zamak No. 2, which tends to eliminate some slight difficulties experienced in casting thin sections having large cores.

A patent was granted recently on a new alloy[8] containing approximately 4 per cent of aluminum, 0.1 per cent of magnesium and 95.9 per cent of high-purity zinc[9]. This alloy has about 25 per cent less tensile-strength than the 4-3-0.1 alloy, but seems to be better in impact strength and apparently undergoes less dimensional change upon aging. While its casting properties are fully equal to those of the 4-3-0.1 alloy, it is too early to predict what its commercial status will be. In fact, Zamak No. 2, the 4-3-0.1 (or 4-3-0.05) alloy made with high-purity zinc, that is, with Horse Head Special, gives such good performance in service that I have never heard of any complaints from cases in which the pure unadulterated alloy was properly employed. The foregoing is the most popular zinc die-casting alloy today, and the confidence engineers have in it undoubtedly is well merited.

Die-Casting-Alloy Investigation

A rather complete investigation of the commonly used commercial zinc die-casting alloys has been instituted recently by Committee B-6 of the American Society for Testing Materials. As a result of this work,

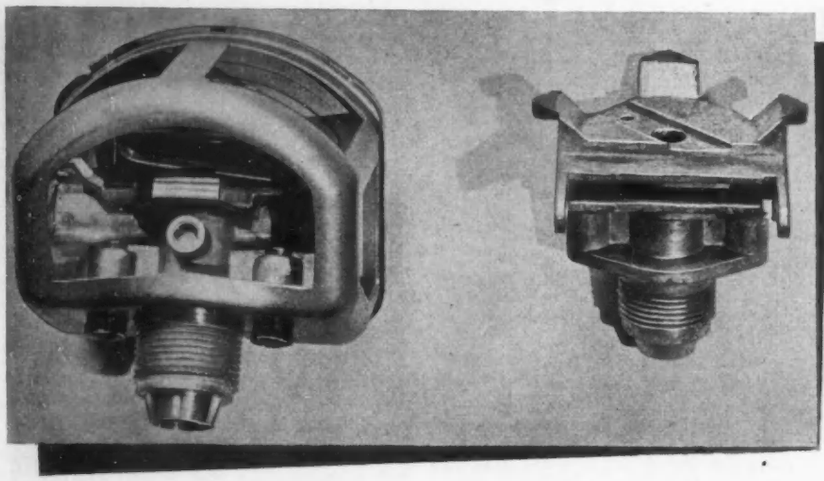


FIG. 5—MAIN FRAME OF THE A C SPEEDOMETER

This Is Die-Cast of an Alloy Containing 4 Per Cent of Aluminum, 3 Per Cent of Copper and 0.1 Per Cent of Magnesium, the Balance Being High-Grade Zinc. Accuracy and Performance Are Obtained Through the Use of Properly Formulated Alloys

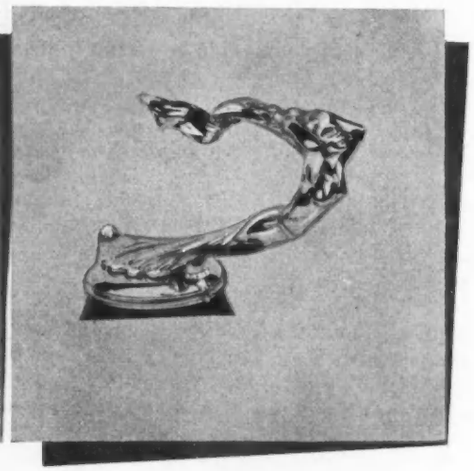


FIG. 6—DIE-CAST ORNAMENTAL-OBJECTS FEASIBLE

The Manufacture of Ornamental Objects of Intricate Design Is Specially Suited to the Die-Casting Process. Careful Die-Design, together with the Use of Properly Formulated Zinc-Base Alloys, Results in Castings Having a Smooth Fine-Grained Surface Well Adapted for Plating. The Radiator-Cap Ornament Shown Was Finished in Chromium-Plate Deposited over a Primary Plate of Nickel

the subcommittee charged with the writing of specifications for zinc-base alloys has suggested the following composition:

	Per Cent		Per Cent
Aluminum	3.50 to 4.50	Cadmium	0.005 max.
Copper	2.50 to 3.50	Tin	0.005 max.
Magnesium	0.05 to 0.12	Other impurities	0.020 max.
Lead	0.010 max.	Zinc	Balance

It is further recommended that the impurities in the zinc used in producing this alloy shall not exceed 0.02 per cent. Because this composition probably represents the best all-round alloy commercially available at this time, its properties are summarized in Table 2.

Alloys of this type are now being extensively used in the production of the following die-cast automotive parts: speedometer frames (See Fig. 5), tachometer frames, instrument panels, radiator caps (See Fig. 6), steering-wheel levers, oil-filter covers, oil-gage parts, fuel-pump casings, carbureters, gasoline-strainer covers, body hardware, vacuum-tank covers, electric and pneumatic windshield-wiper housings, cowl bars, windshields (See Fig. 7), locks, magneto housings, generator end-brackets, distributor housings, tail-lamp bodies, fender-lamp bodies and bases, cowl lamp-brackets, windshield set-screws, taximeter housings, rumble-seat steps, body moldings and numerous other items.

Die-Cast Zinc-Alloy Gears

While die-cast gears made of zinc-base alloys have certain obvious limitations, their properties are such as to merit consideration where proper lubricants can be used and where the loads are reasonable. Several years ago a rather thorough investigation was undertaken in a technical-school laboratory in cooperation with engineers of a certain company which specialized in manufacturing gears. The principal object of this investigation was to study the wear resistance of zinc-base die-cast gears in comparison with standard cut brass-gears. The results were so decidedly in favor of the die-cast gears that further tests were made in comparison with cut gears of cast iron and of steel. The results of these investigations are briefly summarized as follows:

(1) Die-cast zinc-alloy gears deteriorate more rapidly than cut brass-gears when lubricants containing acid animal-fat are used.

(2) Where no lubricant was used and where lubricants showing no acid reaction were employed, the die-cast zinc-alloy gears showed a very marked superiority over brass gears with regard to wear.

(3) Cut brass-gears have better wearing qualities than die-cast zinc-gears when kept thoroughly lubricated with light mineral-oil.

(4) Cast-iron gears were better than die-cast zinc-gears under the same conditions as those in item (3).

(5) When the gears are run dry, the die-cast zinc-alloy gears are superior to steel gears.

(6) The die-cast zinc-alloy gears required a breaking load of 3461 lb. per in. of face as compared with 1996 lb. per in. of face for cast iron.

While the foregoing tests are not complete in every

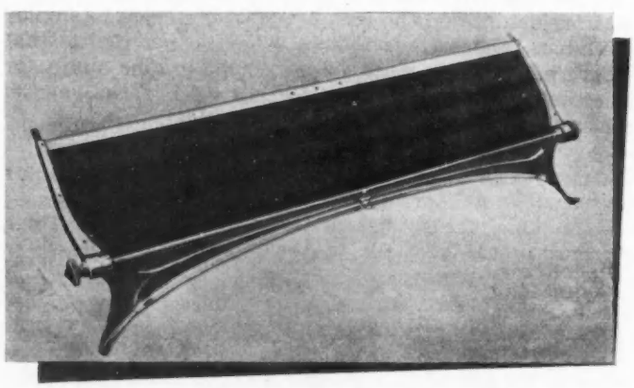


FIG. 7—ZINC-BASE DIE-CAST WINDSHIELD

Except for the Steel Strip Across the Top, the Entire Windshield Shown Is Composed of Zinc-Base Die-Castings. The Cowl Bar, Two Side-Pieces and Set-Screws Are Cast of the "4-3-0.05" Alloy and Are Finished in Chromium-Plate

respect, they definitely indicate that, where the proper alloy is used, a die-cast zinc-alloy gear has relatively good wearing-properties, especially when a lubricant cannot be constantly applied; and that, in comparison with cast iron, the impact strength of the zinc alloy is much greater than that of cast iron. This is further substantiated by the Charpy impact-test as applied to these materials. At present, assemblies for regulating seats, windows and windshields successfully employ the use of die-cast zinc-alloy gears. They are also used in connection with the roadside gasoline pump. No doubt they would serve equally as well in other places.

Zinc Alloys for Body Hardware

A large tonnage of zinc alloy is consumed in the production of body hardware (See Fig. 8). The fine-grained, smooth cast-surface obtainable through the use of polished dies which are properly gated and vented to eliminate "run marks" is especially suited for attractive plated finishes. Nickel, of both dull Butler silver and bright finishes, chromium, and even gold and silver are readily applied, the last two metals being applied over a primary nickel-plate coat.

Practically all cars are equipped with fuel-pumps and carbureters which are essentially composed of zinc-alloy die-castings. Laboratory corrosion-tests have shown that reasonably good commercial gasolines, including Ethyl and High-Test, have no corrosive effect on zinc or zinc alloys. Specimens immersed for a year in a half-dozen different commercial fuels as obtained from roadside pumps were in no way attacked. Specimens immersed in the same fuels to which water had been added underwent slight corrosion with the formation of a very slight amount of fluffy white precipitate in those areas which came into contact with the stagnant water. Similar results were obtained with cast iron or brass, except that the precipitates obtained were darker in color.

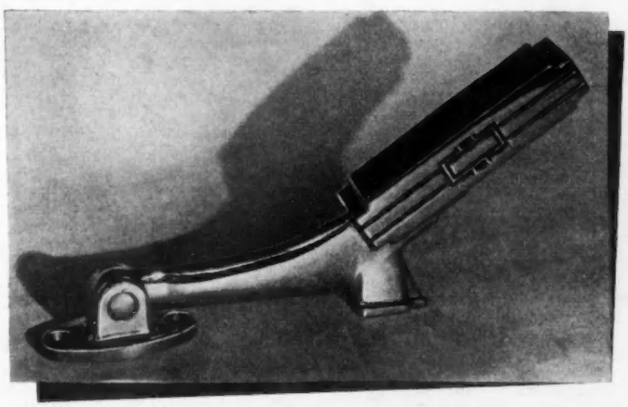


FIG. 8—ZINC-BASE ALLOY DIE-CAST BODY-HARDWARE

A Large Portion of the Total Consumption of Zinc-Base Die-Casting Alloys Used in the Automotive Industry Is Utilized in the Production of Body Hardware. The Casting Shown Is a Foot-Rest Bracket Finished in Bright Nickel and Decorated with Black Enamel. Production by the Die-Casting Method Lends Itself to Practically Unlimited Possibilities in Design

Fuels containing water which is not allowed to remain stagnant for a long period have no appreciable effect. To my knowledge, no corrosion difficulties have been reported in connection with the fuel-pump or vacuum tank. Several isolated complaints have been received pertaining to carbureters, but these installations were made without the use of a filter, and it is probable that water was allowed to remain stagnant in the bowl for a considerable length of time. Under such conditions, the same results might be expected from any other commonly used metal or alloy.

It is well to point out that care should be taken in the design of parts which are to come into direct contact with the hot parts of the engine. It is not practical to use zinc-alloy die-castings where they will be subject to high temperatures. These alloys melt at about 393 deg. cent. (739 deg. fahr.) and undergo undesirable changes in physical structure at about 260 deg. cent. (500 deg. fahr.). Through the use of the proper alloy, that is, 4 per cent of aluminum, 3 per cent of copper, 0.05 to 0.10 per cent of magnesium and the balance high-purity zinc, carbureters of the type shown in Fig 9 have given very satisfactory service. The cast iron is used in that portion subjected to high temperatures and is separated from the lower die-cast zinc-alloy half by insulating material ¼ in. thick. In the early application of zinc alloys for carbureters, some trouble was experienced with dimensional changes. Such experiences can be avoided by the use of suitable alloys.

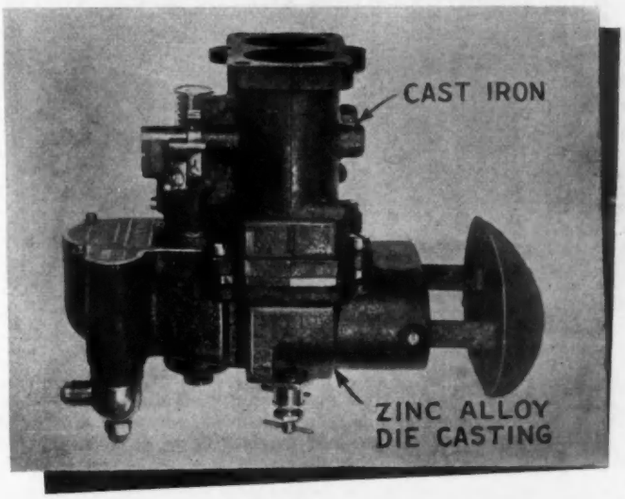


FIG. 9—ASSEMBLY OF IRON AND OF ZINC-ALLOY CASTINGS

Duplex Carbureter Composed of Die-Cast Zinc-Alloy for the Lower Half (See Fig. 10) and Cast Iron for the Upper Half. The High Temperature to Which the Upper Half Is Subjected in Service Makes It Advisable To Use Cast Iron. Both Castings Are Sprayed with One Coat of Black Crystalline Finish, Crystallized for 15 Min. at 125 Deg. Fahr. and Baked for 30 Min. at 375 to 400 Deg. Fahr.

Recent Improvements in Zinc Alloys

It is interesting to note the improvements that have been made in zinc alloys even within the last year. The following data were obtained through the study of five different zinc alloys cast into the part illustrated in Fig. 10. All castings were subjected to the extremely accelerative effects of steam at 95 deg. cent. (203 deg. fahr.) for 20 days. The section indicated by the arrow, approximately of 4.36-in. dimension, was carefully measured with precision instruments before and after exposure and showed the following dimensional change:

Alloy	In.
A	+ 0.049
B	+ 0.038
C	+ 0.006
D	+ 0.004
E	+ 0.002

The composition of alloy *C* is the one which has been generally recommended throughout this paper. Alloys *A* and *B* are in extensive commercial use today and, in most instances, are performing very satisfactorily. Alloys *D* and *E* are still somewhat in the experimental stage. As alloy *C* can be obtained for the same price as alloys *A* and *B*, it is usually specified to obtain the maximum degree of safety.

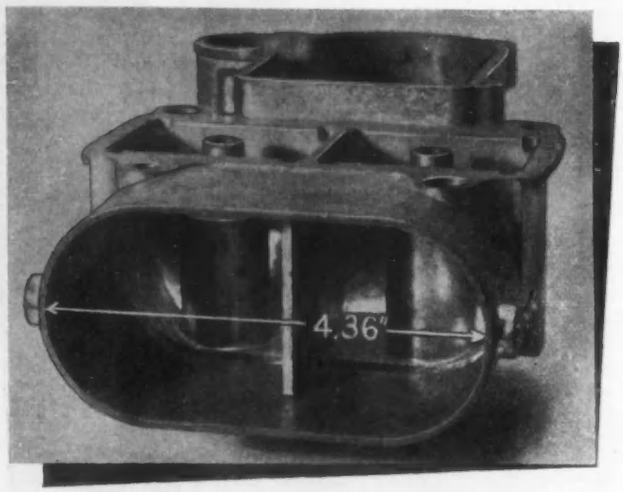


FIG. 10—BODY OF CARBURETER ILLUSTRATED IN FIG. 9

This Body Is Cast of an Alloy Containing 4 Per Cent of Aluminum, 3 Per Cent of Copper, 0.05 Per Cent of Magnesium, Less than 0.005 Per Cent of Cadmium, Less than 0.010 Per Cent of Lead and Less than 0.005 Per Cent of Tin; the Balance Is High-Grade Zinc

Fuel-pump covers (See Fig. 11) experimentally cast of alloys *A* and *E* and exposed under the same accelerated conditions, showed alloy *A* to grow 0.0327 in. on a 5-in. section, while alloy *E* showed a dimensional change of 0.0004 in. on the same section.

The die-cast raditor-cap illustrated in Fig. 12 was removed from my car after 18 months in service. Only water and denatured alcohol had been used in the cooling system. It is interesting to study the cause of failure, which was primarily due to intercrystalline oxidation. Analysis showed that the cap was die-cast of the following alloy:

	Per Cent
Aluminum	4.050
Copper	3.050
Magnesium	0.005
Lead	0.059
Cadmium	0.025
Tin	0.010
Iron	0.014
Zinc	Balance

This is the commonly designated 4-3 alloy containing but a trace of magnesium, not enough to be effective under the existing conditions. The lead content would be considered high in the light of the A.S.T.M. specifications now under consideration, but probably would not have caused the failure had 0.1 per cent of magnesium been present and had the cadmium and tin contents not been abnormally high. The cadmium and tin contents should each have been less than 0.005 per cent. The 0.014 per cent of iron has no appreciable effect. The presence of almost 0.10 per cent of lead-cadmium-tin caused intercrystalline oxidation, that is, corrosion between the crystal boundaries, which phenomenon is greatly accelerated in the presence of heat and moisture.

When a metal corrodes, the resulting products of oxidation increase the volume of the original metal. While the chemical changes which occur in the corrosion process are very gradual, they are very definite and are not restricted by the pressure or adhesion of the surrounding crystals. As the corrosion penetrates the casting, the inter-

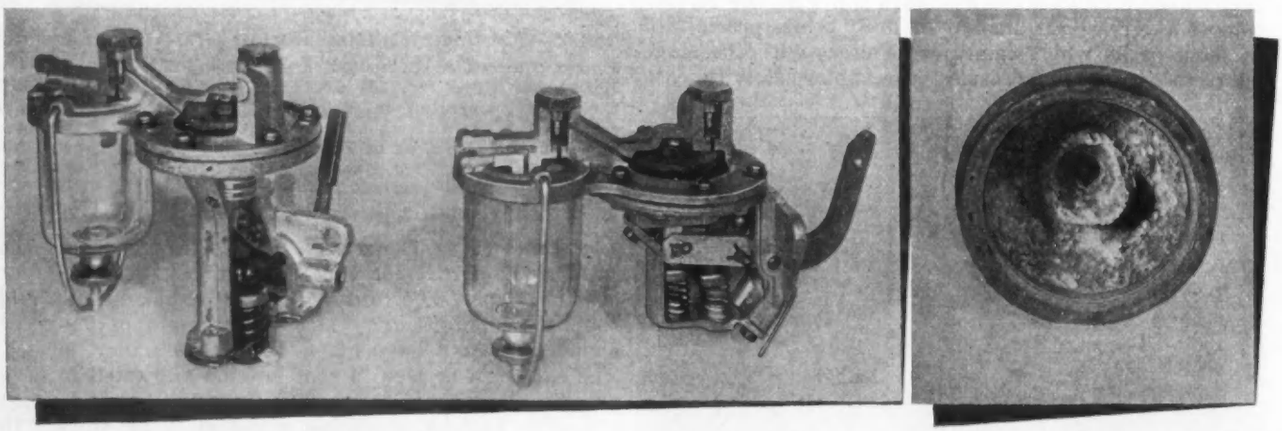


FIG. 11—TWO SECTIONALIZED MODELS OF THE A C-TYPE FUEL-PUMP

Each Pump Is Composed of Two Zinc-Alloy Die-Castings. The Selection of the Alloy Composed of 4 Per Cent of Aluminum, 3 Per Cent of Copper, 0.1 Per Cent of Magnesium and 92.9 Per Cent of Zinc Has Resulted in Strong, Sound Castings Having Physical Properties Necessary for the Service They Must Perform. Every Casting Is Carefully Tested at an Air Pressure of 25 to 30 Lb. Per Sq. In.

FIG. 12—EXAMPLE OF INTERCRYSTALLINE OXIDATION

A Radiator Cap Cast of an Inferior Grade of Zinc-Base Alloy Which Has Failed in Service Due to Intercrystalline Oxidation Is Shown. This Cap Contained 0.085 Per Cent of Lead Plus Cadmium, and 0.01 Per Cent of Tin. According to the Recently Suggested A.S.T.M. Tentative Specifications, the Maximum Allowable Lead-Plus-Cadmium Content Is 0.015 Per Cent and the Maximum Tin Content Is 0.005 Per Cent. Similar Caps Made of an Alloy Containing 4 Per Cent of Aluminum, 3 Per cent of Copper, 0.1 Per Cent of Magnesium and the Balance of High-Grade Zinc Have Given Excellent Service

granular cementing-material undergoes a chemical and a physical change, at the same time losing its cementing power and thus weakening the structure of the alloy. The increase in volume naturally causes growth and, ultimately, the disintegration of the casting. The causes and mechanisms of intercrystalline corrosion are now well understood and, with the newer alloys, this difficulty is eliminated. The 4-3-0.1 alloy with high-purity zinc as a base metal is now specified for these caps and similar failures have not been encountered.

The Zinc-Aluminum-Alloy System

The aging of zinc-aluminum alloys of the type employed for die-casting is usually accompanied by a dimensional change and, likewise, a change in physical properties. It is important for the engineer to know something of this aging phenomena so that he can understand the great improvements that have been made in zinc die-casting alloys in the last few years. Aging may be due to (*a*) intercrystalline corrosion and (*b*) to a phase change within the alloy itself. Intercrystalline oxidation has already been discussed. It is quite well understood and has been eliminated in the newer alloys containing Horse-Head Special zinc, especially where 0.05 to 0.10 per cent of magnesium is present. The phase change which takes place in the zinc-aluminum system has been studied by W. M. Peirce and E. A. Anderson, of the research division of the New Jersey Zinc Co., and by others. I am indebted to Mr. Peirce for the following information pertaining to the zinc-aluminum-alloy system, a study of which is the basis for understanding the behavior of the zinc-aluminum-copper-magnesium alloys in which we are interested.

Data on Zinc-Aluminum-Alloy System

Somewhat less than 1 per cent of aluminum enters into solid solution with zinc to form a homogeneous alloy consisting of a single phase known as the alpha phase. Zinc added to aluminum in amounts up to the neighborhood of 20 per cent enters into solid solution to form a homogeneous alloy consisting of the gamma phase. Zinc-aluminum alloys containing from 1 to 21 per cent of aluminum, between the freezing point and about 270 deg. cent. (518 deg. fahr.), consist of an eutectic of alpha and a new phase or constituent known as beta, together with an excess of alpha if the aluminum content is less than 5 per cent or with an excess of beta if the aluminum content is greater than 5 per cent.

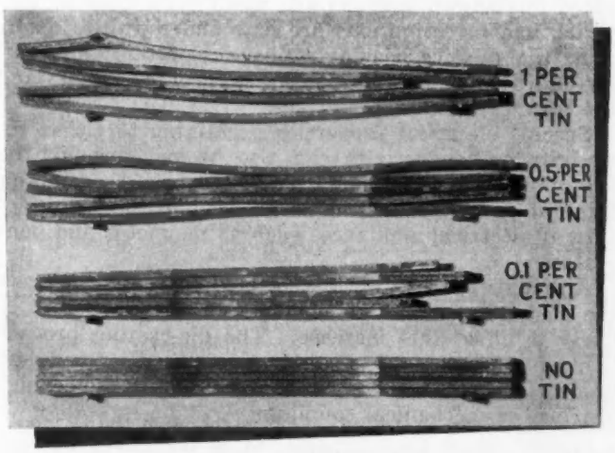


FIG. 13—RESULTS OF ZINC-ALLOY CONTAMINATION

Tensile Bars Cast of the "4-3-0.1" Alloy Contaminated with Various Amounts of Tin and Photographed after 60-Days' Exposure to an Atmosphere Saturated with Water-Vapor at 70 Deg. Cent. (158 Deg. Fahr.). This Exhibit Distinctly Shows the Deleterious Effect of Tin Contamination. Tentative A.S.T.M. Specifications Now Under Consideration for this Type of Alloy Limit the Tin Content to a Maximum of 0.005 Per Cent

At a temperature of about 270 deg. cent. (518 deg. fahr.) this beta constituent is transformed into a mixture of alpha and gamma, which transformation is accompanied by a decrease in volume and an evolution of heat. In the pure zinc-aluminum alloys the transformation is quite rapid. Certain elements such as copper, magnesium and nickel, which may be added to these alloys, have a very pronounced effect on the rate of transformation and, hence, on the resulting properties of the alloys. The presence of 3 per cent of copper in an alloy containing 4 per cent of aluminum prevents the transformation from occurring immediately in alloys that are die-cast. The transformation, however, does occur slowly at room temperature; but it probably requires several years to complete. The addition of magnesium and nickel, either separately or together, further retards this change to a degree that is quite satisfactory for commercial application of this type of alloy in die-castings.

Heat-Treatment of Zinc-Base Die-Casting Alloys

Peirce has also pointed out that the transformation of beta into alpha and gamma can be accelerated by subjecting the die-cast alloy to elevated temperatures. Phase changes which might normally occur in several years' time can be brought about in a few days at 100 deg, cent. (212 deg. fahr.), or in less time at still higher temperatures. Fairly stable conditions can be obtained within the alloy if the castings are heated for about ½ hr. at 280 deg. cent. (536 deg. fahr.) and slowly cooled to 240 deg. cent. (464 deg. fahr.). This is more or less of academic interest because, under normal conditions, the 4-3-0.1 alloy as die-cast serves very satisfactorily in all the applications previously noted.

Water-Vapor Tests

As already mentioned, the first serious difficulties encountered with zinc-alloy die-castings resulted from exposure to high humidity and relatively high atmospheric temperature. This suggested the use of artificial atmospheres, abnormally high with respect to temperature and moisture, as an accelerated means of determining the relative resistance to intercrystalline corrosion of various alloys under observation. As a purely qualitative means of determining the relative properties of zinc alloys, this type of accelerated test has been of considerable value to research investigation. But, like the salt-spray test which is used in the study of plated coatings, it must be used with discretion and understanding.

Tests are made in atmospheres saturated with water vapor at 40, 70 and 95 deg. cent. (104, 158 and 203 deg. fahr.), the lower temperatures requiring longer exposure. Castings that withstand 20 days of exposure to the 95-deg. cent. (203 deg. fahr.) moisture-tests without injury are considered very satisfactory for the present-day commercial applications in the automotive industry. If anything is radically wrong with the alloy of which the die-cast part is made, it will

probably be quite apparent after the 20-day exposure (See Fig. 13).

Disastrous Effects of Contamination

Too much emphasis cannot be placed upon the importance of keeping the die-casting free from contamination, for the inherent quality of the finished product is, for the most part, governed by the impurities in the alloy from which it is made. Lead, cadmium, iron and tin are the impurities most likely to be found in zinc-alloy die-castings. Lead, cadmium and iron may originate in the zinc from which the alloy is made. Both lead and tin may be present through careless contamination in the alloy or in the die-casting plant.

The effect of lead and cadmium is shown in Fig. 12. If Horse-Head Special or an equivalent of high-grade zinc is used in the manufacture of the alloy from which the die-casting is made, and if proper care is exercised in the die-casting plant to prevent contamination, no trouble should be experienced from this source.

The effect of abnormal iron-content is not as serious as abnormally high lead or high cadmium-content. High iron-content is likely to affect the fluidity of the alloy when being die-cast, and may result in surface defects on the finished castings.

Tin is an extremely undesirable impurity. It will cause early failure due to excessive dimensional changes, warping, swelling and cracking, all of which are accompanied by a marked loss in tensile and in impact strengths. Fig. 13 illustrates the effect of tin when added to a perfectly good zinc-base alloy of the 4-3-0.1 type. The tin content of the finished casting should be less than 0.005 per cent.

Physical Tests on Die-Casting Alloys

Tensile strength, percentage of elongation, impact strength, compressive strength, and Brinell, Shore scleroscope and Rockwell hardness have all been determined for the commercial zinc die-casting alloys. The tensile strength is determined with a pulling speed of 0.266 in. per min. Both round and flat test-specimens are used because each represents a different structure which might be obtained in a commercial die-casting. The flat test-specimens, $\frac{1}{8}$ x $\frac{1}{2}$ in., usually indicate slightly higher strengths because they are more readily chilled in the casting process and hence possess a finer grain. The center of the round bar, of $\frac{1}{4}$-in. diameter, has a coarser grain structure because it cools less rapidly. The percentage of elongation is usually determined from the round tensile-strength-test bar pulled at a rate of 0.266 in. per min. Measurements are made on a 2-in. gage-length.

The impact strength, or resistance to breakage by impact forces, is determined on a machine of the Charpy type, using the $\frac{1}{4}$ x $\frac{1}{4}$-in. square test-specimen die-cast in the A.S.T.M. die. The energy absorbed, divided by the area of the cross-section, is calculated to foot-pounds per square inch. Compressive strengths are determined by machining die-cast specimens into cylinders 1 in. in diameter and 2 in. long. These are then tested in a 100,000-lb. capacity Olsen machine. Brinell hardness is determined on the end of the flat die-cast tensile-strength test-specimen using a 10-mm. ball with a 500-kg. load for 30 sec.

Inserts in Zinc-Alloy Die-Castings

Inserts are sometimes employed to impart greater strength or elongation at localized points, affording the properties of a wrought structure where a cast structure would not serve satisfactorily. Door-handle inserts, as shown in Fig. 14, exemplify this use. In this connection I recall previous discussions in which much skepticism was displayed on the part of the automotive engineer as to the possibility of inserts coming loose in the casting. Such fears are unwarranted in the present zinc alloys, for the shrinkage of the alloy is sufficient to anchor it very firmly in the casting. It is virtually impossible to twist it loose, and the casting must be broken before it can be released; but breaking the casting is not an easy task.

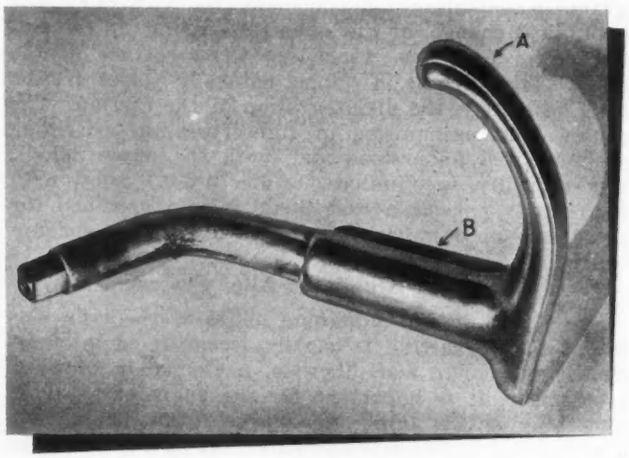


FIG. 14—INSERTS IN ZINC-ALLOY DIE-CASTINGS

An Outside Door-Handle Die-Cast with Steel Insert Is Shown. This Handle Was Placed in a Vise and Was Severely Hammered at *A* and *B*. Hammering at *A* Caused a Considerable Deformation of the Handle without Breakage, Indicating Toughness. Severe Impact Blows at *B* Failed To Break the Casting from the Steel Insert but Caused a Marked Deformation in the Insert Rather Than in the Alloy

Inserts are occasionally used to give hardness or special wearing qualities and are also employed to afford the special bearing properties of the bronze alloys. It is interesting to note that Zamak No. 2, the 4-3-0.05 alloy, has shown considerable merit as a bearing material, and investigations are now under way to determine the relative bearing properties of this and similar alloys as compared with brass, bronze, babbitt and the like.

Specific electrical properties pertaining to either resistivity or conductivity can also be had through the use of inserts. Laminated pole-pieces can be made an integral part of a casting to be used in the manufacture of electrical appliances such as magnetos and generators.

Although the use of inserts obviously will increase the cost of casting, an economy in assembly cost is likely to offset this increase. The die-casting process is much more versatile in this respect than many other production methods which involve welding, soldering, brazing, or mechanical couplings.

Comparative Data

I am frequently asked to compare the physical properties of zinc-base die-casting alloys with other engineering materials such as brass, bronze, cast iron and aluminum alloys. Owing to the wide variation in the figures available for these materials, it is rather difficult to make an accurate and fair comparison.

A study of the average physical properties designated for the various commercial non-ferrous alloys as representing General Motors Corp. Standards[10] affords a basis for comparison. Commercial red-brass castings containing 85 per cent of copper, 5 per cent of tin, 5 per cent of lead and 5 per cent of zinc run 27,000 lb. per sq. in. with 15-per cent elongation in 2 in. Commercial yellow-brass castings containing 63.5 per cent of copper, 3 per cent of lead and 38.5 per cent of zinc run 25,000 lb. per sq. in. with 20-per cent elongation in 2 in. General hard-bronze castings containing 88 per cent of copper, 7 per cent of tin, 2 per cent of lead and 3 per cent of zinc run 30,000 lb. per sq. in. with 12-per cent elongation; and standard phosphor-bronze castings containing 80 per cent of copper, 10 per cent of tin, 9.85 per cent of lead and 0.15 per cent of phosphorus run 28,000 lb. per sq. in. with 8-per cent elongation.

If we take the figures given for Zamak No. 2, 4 per cent of aluminum, 3 per cent of copper, 0.05 to 0.10 per cent of magnesium and the balance Horse-Head Special zinc, we have an average tensile strength of 47,500 lb. per sq. in. with an elongation of 3.7 to 4.3 per cent. By comparison, the tensile strength of Zamak is more than 50 per cent greater than that of cast brass and about 50 per cent greater than that of the cast bronzes. The percentage of elongation and the impact strength of both cast brass and cast bronze are greater than of die-cast Zamak No. 2, but the toughness of the die-cast zinc-alloy is greater than that for cast brass and for cast bronze.

The properties of aluminum die-casting alloys as given in a booklet entitled, Alcoa Aluminum Die-Castings[11], gives average tensile-strengths ranging from 29,000 to 36,000 lb. per sq. in., with average percentages of elongation of from 1 to 3.5 per cent in 2 in. The physical properties of standard zinc-base alloys are given in the same booklet as 45,000 lb. per sq. in. tensile strength and 4.5-per cent elongation. The tensile strength of Zamak No. 2 will run at least 25 per cent higher than that of cast iron, while the elongation is at least 1000 per cent greater. The original impact value for the zinc-base alloy is at least 10 times that of cast iron. As has been mentioned, lead-base and tin-base alloys are relatively weak and their use is restricted to definite fields where definite chemical or bearing properties are desired.

Plating Technique

It has already been stated that rolled zinc, rolled-zinc alloys and zinc-base die-castings can be plated with no more difficulty than that ordinarily experienced with other commonly used metals. The technique and solutions employed differ somewhat from those used in plating on brass and steel, but the process is no more expensive and the results are quite satisfactory. Undoubtedly such a statement might have met with considerable skepticism several years ago, but recent laboratory investigations supplemented by commercial experience have resulted in a simplified plating procedure which will produce dense, adherent coatings quite comparable with those obtained on brass and steel. (See Fig. 15.)

In general, it has been found advisable to first plate the zinc article with nickel. If this procedure is followed, the application of subsequent finishes such as chromium, copper, silver and gold can be carried out in the usual way. It is possible to apply a fairly satisfactory chromium-plate directly on zinc, but usually this requires considerable polishing to effect a bright plate and great care must be exercised to avoid cutting through to the zinc base, which, being very like the chromium in color, is difficult to recognize until it has had time to tarnish.

Die-castings produced in properly designed dies possess a very smooth fine-grained surface which is readily buffed with a free-cutting tripoli on the ordinary loose-stitched-cloth wheel. Of course, rolled zinc and rolled-zinc alloys are easily buffed, due to the smooth rolled-surface.

Cleaning and Other Procedures

Cleaning is perhaps the most important of all operations because improper cleaning will result in pitting, blistering and flaky coatings. Of the numerous cleaning solutions which have been systematically investigated, the following seems most satisfactory[12]: trisodium phosphate (6 oz. per gal. of water) used boiling-hot as an electro-cleaner, with the article as the cathode and with sufficient current to cause gassing. Moore[13] suggests the addition of 1 oz. of sodium hydroxide per gal. and 1 oz. of sodium cyanide per gal. to the solution. In any event, care must be taken to avoid appreciable amounts of strong alkalies or of cyanides, as these promote the formation of dark films on the zinc pieces, the deposition of which adversely affects the adherence of the primary coat.

The use of an acid dip to etch the surface slightly and improve adherence is common practice. Either a weak solution of hydrchloric acid, 10 per cent by vol-

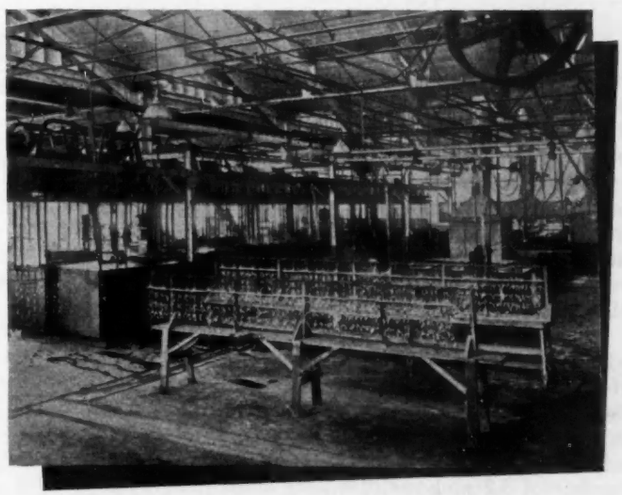


FIG. 15—MODERN PLATING EQUIPMENT

A Plating Room of a Large Modern Die-Casting Plant Is Shown Where Thousands of Zinc-Alloy Die-Castings Are Finished Daily. There is No Limitation as to the Type of Finish Which Can Be Applied to Body Hardware and the Like. While Nickel-Plate, both Dull and Bright, and Bright Chromium-Plate Are Generally Specified, It Is Possible To Apply Gold, Silver or Any Other Metal Commonly Suited to Plating Technique. It Is Usually Advisable To Apply an Initial Deposit of Nickel

[10] General Motors Standards, vol. 11, section *C;* non-ferrous metals.

[11] The Aluminum Co. of America, 1930, Pittsburgh.

[12] See Plating of Rolled Zinc and Zinc-Base Die-Castings; New Jersey Zinc Co. Research Division.

[13] See Die-Casting Practice, by Marc Stern; McGraw-Hill Book Co., Inc., 1930.

ume, or a 1-per cent solution of hydrofluoric acid may be used. Usually a 30 to 60-sec. dip is sufficient, after which the castings or fabricated zinc pieces are rinsed in cold water and are then ready for the plating bath.

The Nickel-Plating Process

As nickel is recommended as a primary coat, irrespective of the final finish, the plating procedure for nickel will be discussed briefly. Subsequent coatings of chromium, brass, bronze, silver, gold and the like can be applied to the nickel in the usual way.

The introduction of metallic zinc into a nickel solution without any current flowing results in the formation of a black, spongy deposit of nickel. Some zinc goes into solution at the same time. The deposits formed are composed, according to Thompson[14], of nickel and zinc intermixed, and are quite useless as corrosion-resistant coatings.

Three methods have been proposed for preventing the immersion deposition: (*a*) increasing the current density in a separate strike solution, (*b*) adding sodium citrate, and (*c*) adding sodium sulphate. The first of these methods is distinctly unsatisfactory. Some streaking invariably occurs even at the highest current-densities and, in any event, the coatings produced are extremely hard and brittle.

The relative merits of the citrate and sulphate additions are open to controversy. While the citrate bath has been used commercially with some success, the higher efficiency, greater throwing-power and greater ease of maintaining the sulphate bath seem to render it the more desirable. The following sulphate bath has been used with good success and is recommended for rolled zinc and zinc-base die-castings:

	Oz. per Gal.	Grams per Liter
Single Nickel Salts	10.00	75
Anhydrous Sodium Sulphate[a]	15.00	113
Ammonium Chloride	1.75	13
Boric Acid	2.00	15

[a] If hydrated sodium is used, add double the quantity.

The best concentration of sodium sulphate in the bath depends upon the size and shape of the articles plated. For a flat object the concentration can be reduced to as low as 8 to 10 oz. per gal. (60 to 75 grams per liter). For complicated shapes, streaking will occur in the recesses unless the sodium sulphate is raised to 15 to 16 oz. per gal. (112.5 to 120.0 grams per liter). Where a number of different articles are being plated in the same tank, the sulphate should be sufficient to prevent streaking in the most complicated object plated.

The sulphate bath operates satisfactorily with zinc when used at room temperature with a current density of 12 to 18 amp. per sq. ft. It is advisable to increase the initial current-density to 30 amp. per sq. ft. for 1 to 2 min. to minimize the danger of streaking. The acidity of the bath should be controlled between a *pH* number of 5.8 and one of 6.2 by additions of ammonium hydroxide or sulphuric acid as required. Should the bath become continuously alkaline, decrease the anode area; or vice versa if an acid condition persists. The connection between *pH* and concentration of hydrogen ion is given by the formula:

$$pH = -\log. \text{ concentration of hydrogen ion}$$

With the current density held between the prescribed limits, it is necessary to maintain the nickel-ion content at 2.0 oz. per gal. (15 grams per liter). The proper nickel-ion content can be maintained by (*a*) regulating the anode area as already suggested and (*b*) adjusting the chloride content of the bath.

The plating time can be reduced somewhat by increasing the nickel-ion concentration to 4 oz. per gal. (30 grams per liter), the sodium-sulphate content to 30 oz. per gal. (225 grams per liter) and the current density to 15 to 30 amp. per sq. ft. The tendency toward streaking is greater in this bath than in the recommended solution, and much more accurate control of the plating conditions is required to secure uniformly good results. Agitation of the articles being plated reduces porosity and permits the use of higher current-densities. With certain shapes, agitation will be found absolutely necessary for successful plating.

In general, it has been found that good coatings having excellent corrosion resistance can be produced from the sulphate bath operated under the recommended conditions. Other than the effects due to size and shape, there seems to be no essential difference between good plating-practice for rolled-zinc stampings and for zinc-alloy die-castings. Moore[15], likewise, recommends the nickel solution already noted. Tentative plating-data to be published, if approved, in the non-ferrous-metals section of the S.A.E. HANDBOOK under General Information, mentions the desirability of the high sulphate-content bath in connection with plating zinc or zinc alloys and suggests the following solution:

	Grams per Liter
Nickel Sulphate $NiSO_4 . 7H_2P$	75
Ammonium Chloride	15
Sodium Sulphate, $Na_2SO_4 10H_2O$	150
Boric Acid	15

It has been suggested that, for ordinary use, this solution may be rather low in sodium sulphate.

Because of the effect of cadmium on the aging properties of zinc-aluminum-copper-magnesium alloys, I am often asked whether cadmium-plate applied directly to the die-casting—that is, to a carbureter—will have any appreciable effect on its aging properties. A series of tests has been made[16] which indicates that cadmium-plate applied directly to the die-casting does not produce any appreciable harmful effect.

Enameling, Japanning and Lacquering

When necessary, it is possible to apply attractive coats of enamels, japans and lacquers to zinc and zinc alloys. Care should be exercised not to use too high a temperature in the baking of enamels and japans to avoid undesirable changes in the physical properties of the casting or rolled-zinc part. Special lacquers which may prove to have advantages over the ones now in use are being investigated.

Summary

Metallic zinc is used in the automotive industry for electro-galvanizing, as a constituent of brass, as rolled sheet and strip for a variety of fabricated parts of

[14] See Nickel-Plating of Zinc and Zinc-Base Die-Castings, by M. R. Thompson; *Transactions of the American Electro-Chemical Society*, 1925.

[15] See Die-Casting Practice, by Marc Stern; McGraw-Hill Book Co., Inc., 1930.

[16] From unpublished data; New Jersey Zinc Co. Research Division.

which running-board molding heads the list, and in the production of a great number of die-cast parts. The marked improvement in both rolled zinc-alloys and zinc die-casting alloys has done much to stimulate added interest in this white, non-ferrous metal, the price and properties of which lend themselves well to effect economy without jeopardizing quality.

Not only have improvements been made in the physical properties of the various zinc alloys, but the application of attractive and durable plated finishes can now be accomplished without difficulty.

The number of parts on the automobile which are made of zinc or zinc alloys is increasing annually. Additional investigations are being undertaken to produce still other zinc alloys having suitable properties for use in a wider range of automotive parts.

THE DISCUSSION

C. S. KEGERREIS[17]:—Die-casting is a very valuable asset of the automotive industry. As all given castings are made from one die, the castings themselves are uniform in their various dimensions. Channels necessarily drilled when other metals are used can, in the die-casting process, be cast originally. This decreases the cost of the final article.

In the last few years the industry has looked with favor upon this type of casting and has perhaps become over-enthusiastic as to its application. Hence it seems highly desirable to have the engineering material presented in the form Mr. Curts has adopted. This aids the engineer in his design and gives him rather definite data as to the working limits to which these alloys can be applied.

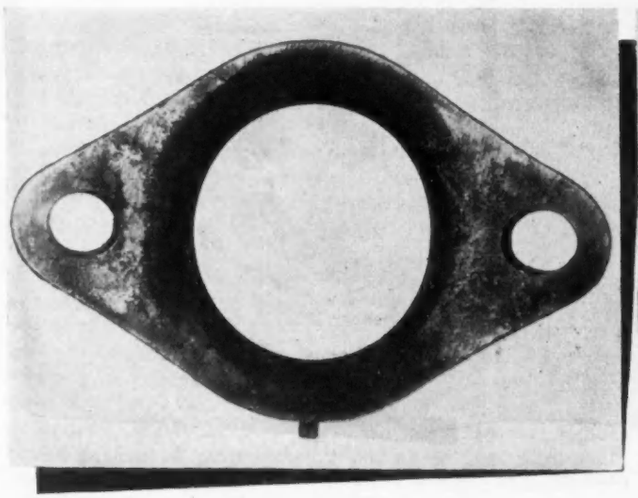


FIG. 16—A DIE-CAST FLANGE WHICH HAS SHOWN DEFORMATION IN SERVICE

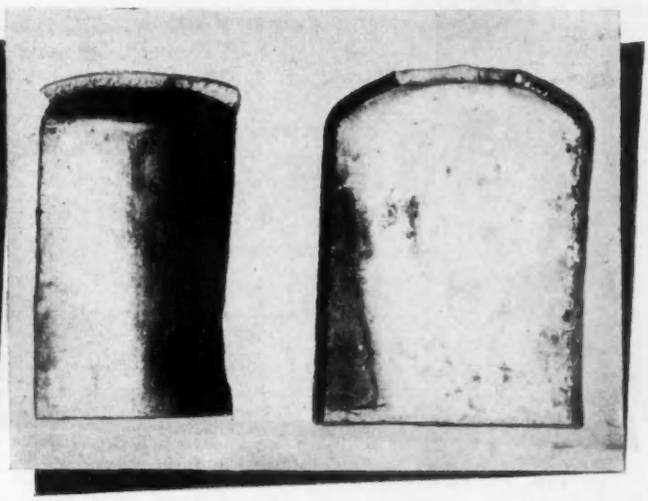


FIG. 17—A SECTION OF A DIE-CASTING (LEFT) SHOWING THE WHITE DEPOSIT CAUSED BY WEATHERING WHERE STAGNANT WATER REMAINED ON A NEWLY MADE CASTING. THE OTHER SECTION (RIGHT) ILLUSTRATES A SIMILAR CASTING THAT IS NOT CORRODED

Every engineer is interested in working particular metals to their maximum allowable stress. In so doing, he must be familiar with the various physical characteristics of all the metals as well as with the chemical constituents. Each metal has a limit of strength, brittleness, porosity and tendency to corrode and decrease in strength at elevated temperatures. When these bounds are overstepped, trouble develops and it sometimes occurs in the field after the casting has left the manufacturing plant.

One particular limit which Mr. Curts has illustrated, and which is very important to the automotive engineer in the design of die-castings, is the undesirable physical changes that occur at 500 deg. fahr. and which result in a decrease in strength. This particular point will aid the engineer to design his product more intelligently. Fig. 16 illustrates a die-cast flange which has shown deformation in service. The metal is of the right specification and the sections are amply heavy for strength; but excessive heat conducted from the heat box in the manifold has caused the bore to warp more than $\frac{1}{8}$ in. out-of-round. This flange has been in service approximately six months, and no doubt its temperature had reached the 500-deg. fahr. value specified. This undue heating effect can well be illustrated when an exhaust manifold often attains a temperature of 1400 deg. fahr. Unless suitable precautions are used in designing the manifold flange, the attached die-casting will of course reach temperatures beyond its working limits.

Another subject often discussed is that of corrosion. This condition occurs in most of the alloys or metals used today. Unless the surface is properly protected, rusting or corrosion occurs in steel and other metals. Fig. 17 shows two sections removed from a die-casting. The section at the left illustrates a white deposit caused by weathering where stagnant water remained on a newly made casting. The other section was exposed to the same humidity, but the water did not remain stagnant on the surface. The finish is the same as when cast. If this casting were plated, enameled

[17] M.S.A.E.—Sales engineer, J. G. Brill Co., Philadelphia.

or painted, using the correct material, corrosion never would have resulted. It may be said that certain attached parts made of steel were badly rusted, which shows that the zinc-base alloy is in many cases less liable to corrosion than is steel.

Purity of Zinc and Zinc Alloys

The phenomenal growth of die-casting has perhaps led to the use of alloys whose characteristics were not very widely known. The ill effects were not discovered by the consumer until after the parts were in service; consequently, neither the casting supplier nor the consumer was able to check the trouble until the matter became serious in the field. Therefore a metal specification became necessary, not only to the company producing the alloy, but also to the organization producing the casting. This assures that the casting is as pure as it is in the ingot form.

Research by the various zinc and zinc-alloy companies has established rather well the specification necessary for proper service, long life and strength. The consummation of this work was reported by Mr. Curts as being recommended by Committee B-6 of the American Society for Testing Materials. This specification will aid all organizations that produce alloys to work to a definite standard. With this specification in mind, the consumer now has definite knowledge by which to control the purity of the metal received in the castings. Hence contamination shown by lead, cadmium or tin can be traced either to the original alloy or to the die-casting shop.

A die-casting organization which casts both tin-base and zinc-base alloys in the same department runs a great risk of contaminating the zinc-base castings. This is particularly true when such small amounts as even 0.005 per cent affect the physical properties. Scrap and sweepings from the tin-base alloy die-casting machines will find their way to the alloying department or to the individual machines which cast the zinc-base metal. This temporarily brings the impurities far beyond their allowable limits.

Fig. 18 illustrates, at the left, a case in which trouble was encountered in service. Checking the results in a steam box brought out the effects illustrated at the end of 72 hr. An analysis was made of the alloy and the contamination found was 0.11 per cent of lead, 0.04 per cent of cadmium and 0.25 per cent of tin. In this case it was not known where the contamination originated, whether in the die-casting plant or in the original alloy.

At the right in Fig. 18, similar effects from checking the results in a steam box after 72 hr. are shown. In this case the contamination is believed to have originated in the die-casting plant. The analysis of the casting showed contamination by 0.09 per cent of lead, 0.03 per cent of cadmium and 0.23 per cent of tin. After discovery of a few instances of contamination, this organization separated the tin and the zinc departments and even segregated the sweepings, as well as attending to various other details to assure the elimination of anything objectional whatsoever in connection with the zinc machines.

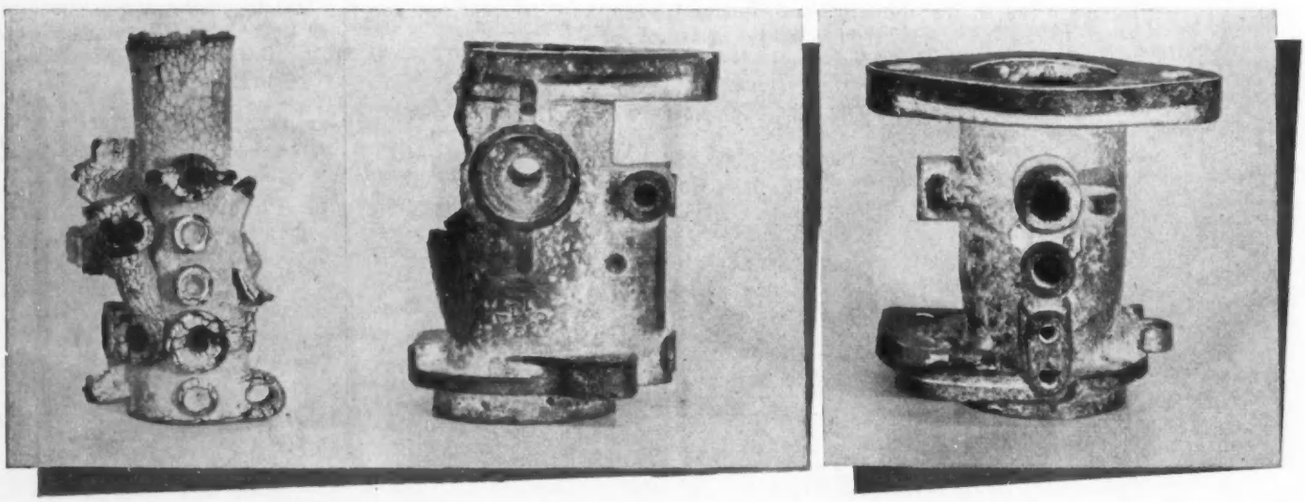


FIG. 18—CONTAMINATION EFFECTS ENCOUNTERED IN SERVICE

In the Casting Shown at the Left, It Was Not Known Whether the Contamination Originated in the Die-Casting Plant or in the Original Alloy. Similar Effects Are Shown at the Right and the Contamination Was Believed To Have Originated in the Die-Casting Plant

FIG. 19—A DIE-CASTING WHICH REMAINED FOR 720 HR. IN A STEAM BATH AND UNDERWENT NO OBJECTIONABLE DEFORMATION

In Fig. 19, the original alloy that was used in Figs. 16 to 18 is shown in a casting which has been placed for 30 days, or 720 hr., in a steam bath. It is evident that the casting is perfectly sound and has undergone no objectionable deformation during this extremely long test.

An analysis shows that the contamination is as follows:

	Percentage	
	Actual	Recommended
Lead	0.040	0.010
Cadmium	0.030	0.005
Tin	Trace	0.005

Most die-casting organizations now realize the seriousness of contamination and have adopted proper policies and production methods to overcome the foregoing shortcomings; consequently, a die-casting today

is a sound and reliable product, whereas those of a few years ago could not always be regarded as sound and reliable.

Porosity has been the cause of some trouble in the past. This is overcome to a large extent by correct die-design and is not necessarily inherent in the alloy. Proper gating and venting will make the thicker sections uniform. Pockets in the castings from improperly constructed dies have been found as large as ¼ in. in diameter. By changing the venting and the method of gating, castings from the same die have been found to be perfectly sound.

This discussion shows the development and progress made because of the mass of information obtained by the die-casting industry during its phenomenal growth in the last several years. It seems that the whole situation can be summarized under three main classifications: (*a*) use of alloys of specified purity, (*b*) in dies properly gated and vented and (*c*) with a production-casting control which obviates unauthorized use of scrap metal.

Temperature Effects on Die-Castings

P. W. DESROCHES[18]:—In connection with the use of die-castings for refrigerator-compressor work, since temperature changes of 50 deg. cent. (90 deg. fahr.) are obtained almost every time the compressor starts to operate, I have several questions to ask. The paper states that tests on die-castings have been conducted at a temperature of 95 deg. cent. (203 deg. fahr.). This seems to me to be rather a low temperature, because a temperature change of 95 deg. cent. is easily attainable underneath the hood of an automobile. What is the probable effect of temperature changes in the order of 50 deg. cent. (90 deg. fahr.) in cases in which they occur many times during the course of a day, as would be true in the case of a refrigerator compressor or a part secured to an engine the temperature of which periodically rises and falls?

ROBERT M. CURTS:—I have referred to an atmosphere saturated with water vapor at 95 deg. cent. (203 deg. fahr.), which condition is more drastic than merely subjecting the casting to a temperature of 95 deg. cent. Considering the range of temperatures to which the fuel-pump, carbureter and the like are subjected and knowing that, with respect to temperature, these zinc-alloy die-castings have stood up well under such service conditions, I believe they should perform very satisfactorily for the purpose you have in mind. This would be particularly so with the newer alloys.

MR. DESROCHES:—What is the nature of the changes in dimensions referred to in the paper? It is not clear whether there is a straight linear growth or shrinkage, or simply a distortion. For example, in a hole which was used as a bearing that fitted to close limits, would the hole grow in size, or become smaller, or simply warp?

MR. CURTS:—Dimensional changes in zinc-alloy die-castings are caused (*a*) by intercrystalline oxidation and (*b*) by a phase change which goes on within the alloy. Intercrystalline oxidation has been the most serious factor because it does produce such pronounced growth and warping. Fortunately, through the use of properly formulated alloys, this phenomenon has been virtually eliminated. Dimensional changes due to phase changes within the alloy may be evidenced by either a very slight expansion or contraction. The use of properly formulated zinc-alloys has reduced such changes to an almost negligible quantity.

In the example showing a carbureter part which we have measured across a 4.36-in. section, subjected to 95 deg. cent. (203 deg. fahr.) steam for 20 days and then remeasured, we find that of these commercial alloys, alloy *A* shows a growth of 0.049 in.; alloy *B* a growth of 0.038 in.; and alloy *C* a growth of 0.006 in. Certainly a dimensional change of 0.006 in. in 4.36 in. is negligible. Zamak No. 3 alloy, consisting of 4 per cent of aluminum, 0.1 per cent of magnesium, and 95.9 per cent of Horse-Head Special zinc, actually shows a dimensional change of +0.0001 in. per ¾-in. section after one year of continuous exposure to a 95 deg. cent. dry atmosphere. It may be added that the specification and use of these new alloys should incur no added expense to the consumer, as they all sell for the same price.

MR. DESROCHES:—Regarding difficulties which arise from intercrystalline oxidation, what would be the effect of using die-castings in an atmosphere in which no oxygen whatever is present? This case arises where die-castings are employed in connection with refrigerants such as butane and propane. Is the oxidation referred to caused by trapping of oxygen during the die-casting process or has it been due to atmospheric effects after the die-castings were made?

MR. CURTS:—If the correct zinc-alloy is specified, there should be no anxiety concerning intercrystalline oxidation.

Die-Castings as Bearing Material

MR. DESROCHES:—Regarding the suitability of die-castings as bearing material in cases where speeds are high, relatively, and the loads are low, say up to 100 lb. per sq. in., and the bearing is supplied with plenty of lubricant, it is difficult to get from the suppliers of die-castings data which seem to be in entire agreement. Since others have found it annoying to get conflicting or inadequate data when trying to anticipate difficulties incident to a new design, it would be very helpful to obtain some agreement on just what the facts concerning the particular material are. What is your opinion on this subject when one hears that a material is suitable as a bearing or for any particular use and someone lets it be known that a certain company tried die-castings for a part and had to abandon their use because of troubles?

MR. CURTS:—We are making some comprehensive studies in cooperation with a large-scale manufacturer of bearings on the bearing-material qualities of die-cast alloys and some of the newer rolled-zinc alloys, and we find that the bearing properties seem very promising. For different uses, a bearing must have different properties. At this time we cannot say that this is a good all-round bearing material, although it is a good bearing material under certain circumstances. So far as our experience is concerned, I think it is safe to say that under many conditions the alloy will wear as well as brass and bronze, and that it may wear better.

We have made some straight-friction tests against brass, bronze and other materials. In all cases the zinc-base alloy has outworn the other materials. In fact, if a steel shaft rotates in a die-cast bearing, unless the bushing is absolutely smooth and clean without

[18] Jun. M.S.A.E.—Detroit.

any little rib or mark on it, it is likely to score the steel shaft rather than wear the bearing.

Manufacturers of electric fans are die-casting their housings with zinc alloys and some of them are using the die-cast alloy itself as a bearing surface. Some of the others are still inserting a bronze or brass bushing. The only trouble they had in former days was that, when they used the old-type alloys that underwent intercrystalline oxidation, these tended to change the dimensions just enough to close up the clearances.

CHAIRMAN E. S. MARKS[19]:—We have had very good success for several years in one application in which a hardened-steel shaft runs in an aluminum casting as a bearing, but over and above anything in connection with the die-casting, we have found it absolutely essential that we maintain that shaft at a certain minimum hardness, making certain that there are no soft spots in the shaft.

Cause of Intercrystalline Oxidation

MR. DESROCHES:—I do not clearly understand whether intercrystalline oxidation can take place in atmospheres which contain no oxygen. Is it due to oxygen that probably is trapped in the structure at the time the casting is made? In the case of refrigerants there would be no oxygen whatever in the atmosphere.

MR. CURTS:—Intercrystalline oxidation depends mainly upon the oxygen which comes in contact with certain inferior alloys. Moisture and heat accelerate this phenomenon. It is not due to oxygen entrapped within the casting.

MR. DESROCHES:—Suppose the casting is submerged in a hydrocarbon gas which corresponds to pure gasoline vapor.

MR. CURTS:—Then there should not be any intercrystalline oxidation.

MR. DESROCHES:—In talking with die-casting manufacturers about allowable stress, they have recommended that the structure be built for a stress of about 3000 lb. per sq. in. This seems to me to be a rather low stress in view of the fact that some of the materials have ultimate strengths of about 40,000 to 50,000 lb. per sq. in. Something must be wrong if one must design a structure for a stress of 3000 lb. per sq. in. in a material that will be bent when it reaches such high limits. It seems that one might reasonably increase the value beyond 3000 lb. per sq. in. unless some other condition exists. Anyone who is trying to design a die-casting would be much interested in knowing what the working stress is.

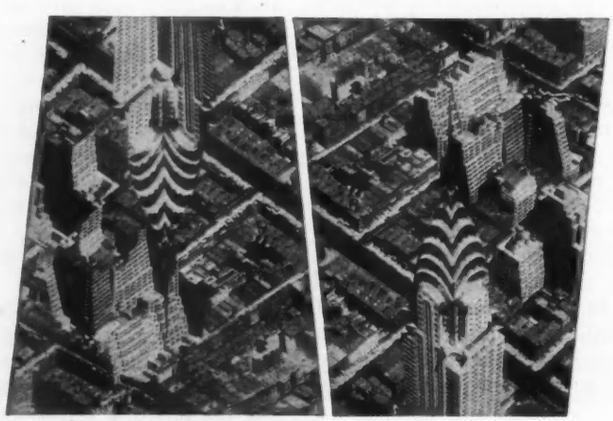
MR. CURTS:—It seems that 3000 lb. per sq. in. is a very low limit. I should like to hear from Mr. Stern regarding this thought.

MARC STERN[20]:—One must bear in mind that the tensile strength as given by test specimens represents ideal casting conditions; but, in a casting of complicated design, one must expect a certain amount of porosity. The typical die-casting consists of a dense outer shell and a small amount of coarser structure toward the center; therefore, the stresses must be considered with that in mind.

With reference to casting strains in die-castings, such conditions prevailed several years ago when the tin-zinc constituent was used, especially with zinc alloys. That was a hot-short metal. By using aluminum, copper and magnesium, the zinc alloys of today are very satisfactory. Further, the machines that are used today are controlled automatically, the cores are pulled out much more rapidly and the time element which causes the metal to shrink is appreciably reduced.

The paper covers one phase of the subject which has not been dealt with in current literature; namely, the properties of zinc alloys. The subject of permanency has been dealt with and the matter of cost of other methods as compared with die-casting has a bearing on permanency. I find that many engineers who are doubtful about the stability of the alloy will provide, say, a 3/16-in. wall, whereas a 3/32-in. wall would be sufficient. The result is that the cost of die-casting is increased and that other metals are found which will serve the purpose more cheaply than will die-casting. If the metal is not satisfactory, the thickness can be increased to be 1 in. So far as proper application of this metal is concerned, ample ribs to increase the amount of chilled surface on the die-castings will increase the tensile strength.

[19] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse.
[20] M.S.A.E.—Manager, die-cast division, A. C. Spark Plug Co., Flint, Mich.



Controlling Factors *in* Machine-Tool Obsolescence

Annual Meeting Paper

By L. A. Blackburn[1]
in Collaboration with J. W. Brussel[2] and A. R. Fors[3]

IN THIS PAPER, obsolescence is considered as concerning the economic value of a machine regardless of its physical condition or age. Improved machinery may make a tool obsolete while it is relatively new. Distinctions are drawn between obsolescence, depreciation and amortization, and a list of controlling and contributing factors in obsolescence is given.

Objection is made to the lumping of obsolescence and depreciation in a single charge, which apparently is not great enough to cover obsolescence with the present accelerated rate of machine-tool progress.

Three examples are given of formulas or methods of determining the economic advisability of purchasing new equipment, and their use is illustrated by being applied to a set of assumed conditions. Yield, risk and liquidity are said to control investments in new equipment, the same as any other investments.

Discussion was presented, mainly by leaders of the machine-tool industry, who advocated improved accounting procedure to give accurate costs. It was said that such accounting would show up wastes and distinguish obsolete equipment. Representatives of one machine-tool group described their method of presenting a balance-sheet showing the economies to be effected by proposed new equipment. The advantages of the standardized system of cost accounting, which has been developed by the National Machine Tool Builders' Association and is being adopted by many machine-tool builders, were presented.

One of the co-authors made strenuous objection to accounting methods which impose excessive burden on the production department for overhead on machine-tools which are of much less actual economic value in production, because of little use or other reasons, than their book value indicates. Attention was called to a feature of the standardized accounting system which discloses short-time utilization of any machine.

In the closure, the production man was said to share with the cost accountant the blame for the failure of accounting systems to give information that is needed by management to show some of the big items in the profit and loss column.

OBSOLESCENCE, for the purposes of this discussion, concerns only the economic value of a machine and not its physical condition. Time therefore is not an element of obsolescence, excepting in so far as it may affect the development of new equipment and the demand for increased quality and quantity and decreased costs.

The physical condition of a certain machine may be as good as on the day when it was built, in fact it may never have been used; yet its economic value may be destroyed if progress demands greater accuracy, finer finishes, or cheaper output than this machine is physically capable of producing while other equipment will meet these demands. Obsolescence is equally effective in destroying the value of a machine in use, regardless of the cause of its failure to meet present requirements, even though the machine might do just as good work as ever.

The real controlling factors in machine-tool obsolescence, as defined herein, are therefore those factors which concern a machine's economic value. Among these are:

(1) A machine's efficiency in competition with improved equipment for doing the same work cheaper or better

(2) Its adaptability for economic service, considering possible changes in product or processing which may eliminate it altogether or reduce its efficiency considerably below that of other available machinery

(3) Its relative efficiency under more stringent requirements of any kind, whether affecting accu-

[1] Consulting engineer, Birmingham, Mich.
[2] M.S.A.E.—Works manager, Timken-Detroit Axle Co., Detroit.
[3] M.S.A.E.—Planning manager, Continental Motors Corp., Detroit.

racy, productivity, or any other element of attainment

(4) The quantitative factor in connection with the time element, which is the required production times the unit saving that would be effected by change in equipment

Other factors which are equally important are:

(5) Policy of the finance committee of the corporation toward return on capital investment, and the existence of an accounting system that will distribute all elements of cost

(6) Stability of product; how long and in what quantities it will be built as it is being tooled at the outset

(7) Growth of the company and of demand for the product, perhaps involving the passing of a company from something like job-shop methods to quantity or mass production

(8) Ability of the tool engineer to design some flexibility into single-purpose machines

(9) Activity of machine-tool builders in research and development

(10) Trend of public mind, as in passing from a single cylinder to sixteen—which involves changes in all attaching parts such as transmissions, brakes, axles, wheels, frames, bodies, paint and sheet metal—all of which are initiated in the car-engineering department

(11) Research and standardization

Agreement may be general that the foregoing factors are those that control obsolescence, but the question of determination of obsolescence is one that cannot be disposed of so quickly and simply.

Establishing Distinctions Between Terms

Two words that are probably used more commonly than obsolescence should be defined before going further, inasmuch as these words are so often used with obsolescence. They are depreciation and amortization.

Depreciation is the act of lessening or seeking to lessen the price or value, the reduction of worth, the gradual wearing out of equipment. It is conceivable that a qualified engineer could calculate depreciation in advance; it deals with the anticipated life of the machine to produce for a given number of hours.

Amortization is the extinction of a debt, usually by means of a sinking fund. Wear and abuse do not necessarily enter into this meaning, but rather an anticipated life or fixed time in which to set aside funds to pay the debt. For example, if we had a contract to produce in volume a six-cylinder engine which at the end of 3 years was to be changed to an eight, the cost of all special machinery should be amortized at the rate of 33 1/3 per cent per year in order to show the true cost.

It is very easy to confuse obsolescence with amortization. As a matter of fact, if we knew in advance what the obsolescence figure really would be, amortization could and should be at a corresponding rate.

We should not fear obsolescence or try to dodge it in any way, because it is a measure of progress, and manufacturers should manage their affairs to meet this cost. Obsolescence is always with us; but all too frequently it does not appear in our ledgers or it is consolidated and thereby obscured by entering, under burden, 10 per cent of the original installed cost of the machine for depreciation. Depreciation is gradual and can be calculated, as we have already shown. This is not true of obsolescence; the facts are hidden in research. Its coming may be sudden; even while a new machine is being installed, another machine may be on the design board that will obsolete the new machine in a year or two.

A splendid example of obsolescence, given by Frederick V. Geier[4], is that of a special machine built in 1924 which doubled the output thereftofore obtained. Within 3½ years a standard machine gave the same productivity, and within 5 years a standard machine doubled the production of the special machine with one-half the capital investment.

Provision Must Be Made for Obsolescence

Obsolescence is a question that has given and is giving the manufacturers a considerable amount of worry; accountants, tax experts, and Government officials have been confronted with this problem. To my knowledge some 25 or 30 formulas have been developed by different individuals and corporations to determine when a machine has outlived its economic value. The Government is undertaking to establish facts and figures relating to obsolescence through the domestic commerce division of the Department of Commerce with Dr. Frank M. Surface, Assistant Director of the Bureau of Foreign and Domestic Commerce, in charge. The Government recognizes the facts that obsolescence differs from depreciation and that a distinct method should be set up for providing against obsolescence as a hazard of business.

Recognition must be given to obsolescence and it must be given financial values if the manufacturer is to avoid financial difficulties. The production man should recognize this fact and provide himself with the information and personnel to keep his equipment on an economical basis. It is quite obvious, then, that such records should be set up for the manufacturer or production man and the accountant or financial man in such a way that accurate information will be available so that the exact conditions existing in the specific manufacturing unit are set forth for actuarial studies on a better basis than average data. This would not be so difficult if suitable steps were taken at the outset to provide such information. It does require however a very close tie-up between manufacturing and accounting, with a definite idea as to what the manufacturing department will require in the way of records to establish the economic value of the specific piece of equipment under discussion.

Replacing Equipment Should Involve No Loss

The value of knowing when equipment is obsolete has been expressed by Dr. Julius Klein, Assistant Secretary of Commerce, who said, in a recent radio talk:

> A factory cannot derive the full benefits and profits that spring from mechanical efficiency unless it keeps its machinery absolutely uptodate, following the progress of invention closely and utilizing the very best and most modern devices that science makes available. This means that the men in charge of a manufacturing enterprise must be willing to junk things to get rid of them summarily when they have outlived their usefulness, and they must calculate matters from the actuarial standpoint, estimating the life prospects

[4] See paper presented at meeting of Machinery Builders Society, New York City, May, 1930.

> in such a way that they can scrap outworn equipment without suffering any serious financial loss as a result. This is of vital interest to us consumers, because old and inappropriate machinery means higher prices to be paid by everybody. . . . These junk piles exist because factory managers in general prefer to have the junk piles outside their factories rather than inside and in use. . . .

Up to about 15 years ago, the factor of depreciation on the major classification of machine-tools was equal to, or greater than the factor of obsolescence. According to a recent survey[5] on machine-tool depreciation, the estimated life of boring and turning machines ranged from 7 to 22 years; drilling-machines and milling-machines, 8 to 25 years; broaching-machines, 6 to 20 years; lathes, 10 to 25 years; and punch-presses, 9 to 20 years. In every case in which special machines came under these headings, their average life was from 2 to 4 years less than that of standard equipment. In another survey[6], it was found that 44 per cent of all metal-working machinery at the beginning of 1926 was at least 10 years old.

> In the 20-year period from 1899 to 1919, the average annual increase in physical production in the United States was 5.6 per cent, the number of wage earners increased 5.15 per cent, the power increased 10.25 per cent and the value of industrial machinery increased about 6.5 per cent. These averages prevail up to 1919. In the 8-year period from 1919 to 1927, the average annual increase in physical production was 5.8 per cent; power increase, 3.67 per cent; labor decrease, 0.36 per cent; and industrial-machinery increase, between 4 and 5.8 per cent. During the 20-year period, the total increase of labor efficiency was only 4.7 per cent. In the 8 years following 1919, labor efficiency increased 53.5 per cent.[4]

From one source we find that 44 per cent of all metal-working machinery in use in 1926 was 10 years old or older. In virtually the same period, according to another source of information, labor efficiency increased nearly 50 per cent in 8 years.

> The answer to this may be found in the report of the Committee on Recent Economic Changes of the President's Conference on Unemployment, the principal conclusions seem to be that in the period 1920 to 1927 . . . acceleration rather than structural change was the key to an understanding of our recent economic development . . . and . . . an important element in the increase in output has been the rapid abandonment of inefficient plants.[4]

Improvements Due to New Efficiency

What was the value of these abandoned inefficient plants and what was the value of the obsolete equipment in them and other plants disposed of during the period of such phenomenal increase of labor efficiency? Certainly we must concede some part of this showing to new equipment. And again, the Bureau of Census figures show that 1919 was the best year in dollars of business that the machine-tool industry has had since the war period. It was also the best for the automobile industry, being over $200,000,000. This is only one side of the proof of the value of new and modern equipment. The value of obsolete equipment is lacking.

I know that we have in the automobile industry today millions of dollars worth of machine-tools that have been over depreciated, that are 10 years old and more. It is also a fact that some of them are producers, making money every day they run. These most likely are standard machines that are correctly tooled and properly placed on jobs that they can do efficiently. What will happen to a large percentage of these machines if 1931 and 1932 prove to be boom years in the automobile industry? The shop men will undoubtedly try to replace a goodly part of them with new and more up-to-the-minute equipment. I have seen this happen. Under such conditions it would be fairly easy to get appropriations to replace old equipment that has earned its original cost. The average manager I believe would consider a 10-year life sufficient for a machine in the automobile industry. He believes in new models, and he would like to keep his shop up to the standard of the car he is making.

We depreciate machines by a systematic method and set up our ledgers to show just what the machine is worth at any time. The book value of the machinery is, for various reasons, written off and entered as a loss. The books do not classify the loss; that has not been deemed necessary. We have our record of over-depreciation itemized to the *n*th degree. We write off millions in unearned dollars, and still enter no detailed information as to whether the cause is change of model or parts, change of product, obsolescence or wearing out of the machine, or one of a dozen other causes. Manufacturing industries need to develop a science of replacement facts that will reveal not only the problem but the solution.

Two Kinds of Obsolescence

Obsolescence can be divided into two major classifications: obsolescence through change in design of product, which does not reflect on the value of the machine as a useful piece of equipment but merely that the part which it was bought to produce was found to be of wrong design or to have short life; and obsolescence through an economic replacement.

Nowhere have we been able to find data that will tell us how much equipment has been discarded and the reasons for discarding it. It seems as though some executives would like to know the history of large sums written off every year and buried in one account. Why not let some of these skeletons walk around a little to create an interest in their history? By the same token, why not provide the old, out-of-date, decrepit equipment with a pair of crutches to parade its wares before the management? What we need are facts, properly prepared and logically set up so that the management will be acquainted with the efficiency of its man power and be able to keep its machine power in line with the business. Many mistakes that are buried in one account would then be set up in separate accounts, and these accounts would fix responsibility.

In view of the fact that no positive information is available on the obsolescence of machine-tools, how are we to protect our industries against unforeseen losses? It is more or less standard practice to use a figure of 10 per cent for depreciation, which is supposed to include obsolescence and amortization. I will not question the accuracy of this as an average figure for all kinds of machinery, too much time has been spent in arriving at it, but if we are to believe such

[4] See paper presented at meeting of Machinery Builders Society, New York City, May, 1930.
[5] See *Automotive Industries*, June 15, 1929, p. 909.
[6] See *American Machinist*, Dec. 20, 1928, p. 943.

men as C. R. Burt, associate professor of engineering standards and measurement at Massachusetts Institute of Technology; F. V. Geier, of the Cincinnati Milling Machine Co.; and many others, manufacturers must depreciate at a faster rate than in the past. In other words, we believe that progress in the machine-tool industry during the last 10 years and the prospects for the next 10 years justify a review of this rate, and the review is likely to result in an upward revision.

Machine-Tool Design Is Accelerating

According to one of the surveys mentioned in the foregoing, some machines have an average life of 25 years. This refers to time only; nothing is said about productivity. Some machinery, regardless of its age, must be kept on certain jobs on which production is low and no new business is in sight against which to figure savings from the purchase of new equipment. The age of the machine may not mean that it is worn out; 25 years may include only 5 years of actual production hours. Engineers formerly considered that the life of machine-tool designs was from 10 to 15 years; today they are convinced that the life of a machine-tool design is not over 5 to 10 years. If this is true, the one thing to show a true return on the investment is to increase the factor of depreciation to include obsolescence.

How are we going to arrive at this figure? How much should it be? Will it require a breakdown into classifications of smaller groups? These are problems for management and accountants to settle, with the tool engineer lending a very valuable helping hand.

> According to the directors of the National Association of Machine Tool Builders, to provide properly for obsolescence, a depreciation rate of 10 to 15 per cent will be necessary hereafter to recover the cost of a machine before it becomes obsolete. A recent survey of the opinions of leading manufacturers gave recommendations ranging from 7 to 33⅓ per cent, the average being 12½ per cent.[4]

These figures seem to cover equipment of both long and short life. Surely this group is in a position to know the trend of the machine-tool industry.

> The frequency with which new models have appeared on the market shows a decided upward trend. . . . The productivity of tools of 14 types and 8 general classes shows a marked upward trend during the last 10 years, indicating over six times the productivity that was available in 1900. . . . The 5-year period centering about 1906 shows a peak in productivity increase and reflects the change brought about by the adaptation of machine-tools to the use of high-speed steel.[4]

Beginning in 1919 there was a very decided movement in the automobile industry to new models in machine-tools. Tool designers, process men, and machine-tool builders were working day and night to develop machines for mass production of more pieces at less direct-labor cost. The cost of some of these machines was staggering, and the results obtained from some of them was sickening, but the automobile industry stood the shock and was not in the least discouraged. Designers were developed to meet the demand, and as a result new models that have greater productivity than the superseded models are coming on the market more frequently. This indicates plainly that obsolescence is growing both in frequency and in degree.

Complicating Problems Are Involved

The greatest industrial expansion of the latter part of the last century took place when industrial research was unheard of, which is rather hard to understand under present conditions. The automobile has grown to be the greatest industry in this Country with research as its background. Can the machine-tool builders overlook this fact? "Industry neglecting research runs a great and unnecessary risk," says Dr. A. D. Little, "it is a form of insurance."[7] And Dr. Little gives several cases of financial disaster that were due to industrial progress of competitors resulting from research on their part.

With the introduction of high-speed tool-steel, the machine-tool industry showed considerable productivity due to the demand for heavier machines to take advantage of increased speeds and feeds. Is it not time for both users and builders of machine-tools to ask themselves how the cemented-tungsten-carbide tool is going to affect the metal-working industry? Mr. Jefferies says it has a possibility of yielding a 20-per-cent increase in production. Are we, as potential users, doing enough research work to know what this new tool can do for the industry? Are we buying wisely, or will the machine-tools being purchased today be obsolete in 2 or 3 years? Manufacturing research is just as essential to the profits of a business as is scientific research to keep a product in demand.

Still another perplexing problem in determining obsolescence is return on investment. Buildings and property are considered an excellent investment when they show a net return of 6 per cent. At the same time we find that 200 of the larger manufacturing companies, in answer to a questionnaire asking if they required a production saving to return the investment on new machinery within a definite time, replied as follows: all required a complete return within 5 years, 40 per cent insisted on a complete return within 2 years, and 60 per cent within 3 years. On this basis, if the actual savings are set up and not passed on to the consumer, the amortization is taken care of in from 2 to 5 years. However, unless I am very much mistaken, the machine is depreciated at the common rate of 10 per cent per year only, instead of at 20 to 50 per cent per year. A greater return on the investment is shown with the 10-per-cent depreciation, but a greater book-value write-off is required at the end of the obsolescence period if the machine is obsoleted within 2 to 5 years. It is true that the two accounts will balance in the end, but the profits and losses are not shown correctly for the various years, which may or may not be serious.

In this age of transferring the burden of production from labor to machinery, the transferred labor gets its expression in burden costs through charges covering depreciation, interest, taxes, power and the like. Here again we must call upon management and the accountant for a distribution of burden to each production center, and to each machine if necessary, in proportion to its demand, and not by any process of spreading a general average burden over everything. Only by allocation of burden to the unit of production can we correctly determine obsolescence.

[4] See paper presented at meeting of Machinery Builders Society, New York City, May, 1930.

[7] See Searching Into the Unknown, General Electric Co.

How can it be determined with so many of the items averaged or, worse still, confused with other items? It becomes quite complicated when the tool engineer presents his problem to the management. He encounters the company's policy regarding such matters as returns and burden, and in nine cases out of ten he will lose his case if he uses the burden from the cost department's set-up.

Let us take an example of a machine which is tagged obsolete. We get quotations on modern machinery to replace it, which the builder claims will produce so many pieces of the part per hour and will give consecutive production over a reasonable time. This, to be significant, must be accompanied by a guarantee from the builder; because failure of such machines to equal the estimated production will soon offset any savings forecast by the builder of the equipment and will cause besides a considerable loss in the plant as a whole by failing to maintain the schedule.

Simple Method for Evaluating Replacement

Let us consider three of the 25 formulas or methods submitted and doubtless being used by different concerns for establishing return on investment in new machines and see how they would apply to our own problems. The Warner & Swasey Co. presents the simplest one, which is as follows:

Gross savings per piece = former cost per piece − proposed cost per piece

Gross savings per year = pieces per day × proposed cost per piece × number of days worked per year

Total investment = cost of new equipment + special tooling

Total depreciation per year = 20 per cent of cost of equipment + 100 per cent of special tooling cost

Net annual savings = gross savings per year − total depreciation per year

For the purpose of discussion only, we have taken a proposal on certain equipment to show the different results obtained by the use of these formulas. The factors used in each case are shown in Table 1.

Substituting the values of Table 1 in the Warner & Swasey formula, we have:

Gross saving per piece, \$0.0449 − \$0.0084 = \$0.0365

Gross saving per year, 1494 × \$0.0365 × 240 = \$13,100

Total investment, including tooling, \$31,413

Total depreciation, per year, 20 per cent of \$31,413 = \$6,282

Net annual saving, \$13,100 − \$6,282 = \$6,818

Therefore, the return on investment is \$6,818 ÷ \$31,413 = 21.6 per cent.

The Warner & Swasey method, however, does not consider the book value of the old machine. Certainly we cannot overlook the fact that there are unearned dollars in the old machine which we have obsoleted, and we have not realized on this basis the full utilization of the previous investment. This formula will give a quick answer for some cases, but certainly it is not accurate to the extent of taking into consideration all the facts.

This brings us to a discussion of the accuracy of our forecast as to working hours per year which we hope our schedule will justify. This is a gamble which accompanies every investment, and we must gamble to a certain extent if we hope to remain the progressive Nation that we are; but we must not lose too often if we wish to stay in business.

S K F Formula Allows for Obsolete Equipment

The S K F formula for evaluating new equipment is:

$$M = \frac{C_e + C_t + C_{ix} + C_{dx} + V_b}{(R_p - R_e)\ N_d D_m + S_{ohm}}$$

in which

C_e = the cost of the new equipment
C_{dx} = the cost of depreciation for three years at 12.5 per cent
C_{ix} = the cost of interest for three years at 6 per cent, representing the number of years determined upon as the maximum time during which the equipment must pay for itself
C_t = the cost of tooling the new equipment
D_m = the number of working days per month
M = the number of months in which the equipment is to pay for itself
N_d = the number of pieces to be produced per day on the proposed equipment
R_e = the estimated rate on the new equipment
R_p = the present rate (cost) per piece
S_{ohm} = the savings in overhead per month
V_b = the book value of the displaced equipment

Substituting the same factors from Table 1 in the S K F formula, we find the number of months required to return the entire investment to be

$$M = \frac{\$31{,}413 + 0 + \$5{,}654 + \$11{,}780 + \$29{,}218}{(\$0.0449 - \$0.0084)\ 1494 \times 22 + \$417}$$

$$= \frac{\$78{,}065}{\$1{,}616} = 48 \text{ months, or } 25 \text{ per cent return}$$

A.S.M.E. Material-Handling Formulas Applicable

The next and most interesting group of formulas is that developed by James A. Shepard and George E. Hagemann for and adopted by the Material Handling Division of the A.S.M.E.[8] This includes formulas for the maximum investment that is warranted for the time required for complete amortization and for the yearly profits. The formulas are as follows:

For maximum investment, Z, in dollars, which will earn simple interest

$$Z = \left[\frac{S + T_a + U - E)\ X - T_b}{A + B + C + D}\right] - K$$

Yearly cost, Y, to maintain mechanical equipment ready for operation, fixed charges, dollars

$$Y = I\ (A + B + C + D)$$

Yearly profit, V, in excess of simple interest, from operation of mechanical equipment, dollars

$$V = [(S + T_a + U - E)\ X + T_b] - [Y + (KA)]$$

Yearly profit from operation, P, in percentage of investment

$$P = \frac{V}{I} + A$$

Time, H, required for complete amortization of the investment out of earnings, years

$$H = \frac{100 \text{ per cent}}{P + D}$$

The factors involved in the foregoing formulas are as follows:

[8] See *Transactions of the American Society of Mechanical Engineers*, Vol. 47, 1925, p. 525.

Debit Factors

A = allowance on investment, per cent
B = allowance for taxes, insurance, etc., per cent
C = allowance for upkeep, per cent
D = allowance for depreciation and obsolescence, per cent
E = yearly cost of power, supplies and other items consumed, dollars

Credit Factors

S = yearly saving in direct labor, dollars
T_a = yearly saving in labor burden, dollars
T_b = yearly fixed charges on equipment which will be displaced, dollars
U = yearly saving or earning through increased production, dollars

Other Factors

I = initial cost of equipment, dollars
K = unamortized value of equipment displaced, less its scrap or resale value, dollars
X = portion of year during which equipment will be operated, per cent

Using the values from Table 1 in the A.S.M.E. formulas we find:

Maintenance Cost

$$Y = \$31,413\ (0.06 + 0.03 + 0.04 + 0.125) = \$8,010$$

Yearly Profit

$$V = [(\$13,100 + \$5,000 + 0 - 0)\ 0.975 + \$3,831] - [\$8,010 + (17,118 \times 0.06)] = \$21,478 - \$9,037 = \$12,441$$

and

$$P = \frac{\$12,441}{\$31,431} + 0.06 = 0.395 + 0.06 = 45.5 \text{ per cent}$$

Time required for amortization

$$H = \frac{100 \text{ per cent}}{0.455 + 0.125} = 1.74 \text{ years, or about 21 months}$$

Values in Table 1 have been selected to make a case in which the advisability of making the investment is not perfectly obvious. Very little figuring is required when the returns are greater than 100 per cent; large mistakes can be made, even, and the investment will still be satisfactory. What we are looking for is some plan whereby the deciding factor of obsolescence will be brought out and presented to management in a clear, simple, convincing way. The problem, in deciding when any particular piece of equipment in a particlar shop is to be replaced by new equipment, is the ability of the new equipment to make sufficient return on the required investment in that specific shop and under the actual conditions to induce the management to invest the required additional capital in the business.

Yield, Risk and Liquidity Dictate Investment

The same elements enter in making this investment that should be considered in making any investment, namely: yield, risk, and liquidity.

Yield may be divided into two classes, visible and invisible. The visible yield is represented by the direct savings effected through the use of the new equipment over the old on probable production. The invisible yield is not so easily ascertained. It takes the form of greater accuracy or a smaller inventory, or it may afford the possibility of working a select crew of skilled men rather than a larger force of average ability.

The risk must be justified by the size of the expected return. One concern, which has a stable production, may think a 15 per cent return on its investment to be sufficient; while another, whose production is susceptible to frequent changes, can with perfect propriety insist on a 50 per cent return.

Liquidity is a minor factor and is represented by a fair salvage value of the equipment. A standard machine for which there is a large demand has a greater liquid value than one in limited demand.

The conclusion to buy a piece of equipment because it will pay for itself within five years usually is based upon the assumption that the present costs will be used to determine selling prices for that period. If the new lower costs resulting from its purchase are the basis of new selling prices, virtually the entire visible yield of the investment may be passed on to the customer in the form of lower prices.

Price studies usually are made on the basis of the latest cost from the cost department. Any capital investment that has been made in previous years on the basis of anticipated saving thus becomes part of a new capital structure on which profits are figured. We have nothing to fear as long as we can show profits on this basis, but how long can we continue to do this? Expert accountants apparently are satisfied with the present methods and will continue to use them until such time as we who are interested in obsolescence set about seriously to convince them that some change is needed.

TABLE 1—ASSUMED DATA FOR PROBLEMS IN OBSOLESCENCE

Units forecast for year,	360,000
Total production required per hour,	166
Present production per machine per hour,	12
Proposed production per machine per hour,	38
Labor rate per hour, assuming 100 per cent efficiency,	$0.70
Present direct labor cost per piece,	$0.0449
Proposed direct labor cost per piece,	$0.0084
Direct labor saving per piece,	$0.0365
Direct labor saving per year,	$13,100
Burden rate per year, per cent,	200
Depreciation rate per year, per cent,	12.5
Book value of old equipment,	$29,218
Total cost of new equipment,	$31,413
Salvage value of old machines,	$12,100
Interest rate, per cent,	6
Taxes, insurance, per cent,	3
Maintenance, per cent,	4
Depreciation and obsolescence, per cent,	12.5
Net book value of old equipment,	$29,218
Gross book value of old equipment,	$38,314
Salvage value of old equipment,	$12,100
Saving in overhead, per year,	$5,000

Total cost of new tooling is included in cost of equipment.
Standard yearly production time per year is considered as 200 days of 19 hr., or 3800 hr. This is 100-per-cent operation.

Production Men Should Study the Subject

What is a good yardstick for obsolescence? It is something that can be measured? Do we admit that it is an economic hazard, so far as metal-working machines are concerned? In the aggregate, is obsolescence of sufficient weight, over and above the depreciation factor, to justify additional expense that may be necessary to find it? These are questions which we think every master mechanic and production executive should be asking himself, and for which he should be looking for answers.

Frederick V. Geier, vice-president of the Cincinnati Milling Machine Co., in a paper on Amortization of Machine Tools[4] says:

> The present plan of depreciating machine-tools on a time basis, usually 10 years, is inadequate, because the machine is ordinarily obsolete before that time

[4] See paper presented at meeting of Machinery Builders Society, New York City, May. 1930.

under present manufacturing conditions. A savings element should replace the time element in calculating depreciation. A reserve, or replacement fund, should be accrued at the rate at which savings result from the use of the new machine. In this way funds would be accumulated for the purchase of its successor during the period when the machine was most productive.

We believe that there is much to be learned about machine-tool obsolescence. It is not a problem that cannot be mastered provided an adequate cost-accounting system is set up that will provide facts, which now are sadly missing, and true costs. These will make it comparatively easy to determine how much better than the old the new machine needs to be. Obviously no one system of figuring cost will be possible; the important point is that the users of equipment must figure costs accurately to determine obsolescence accurately.

THE DISCUSSION

C. D. OESTERLEIN[9]:—Defining obsolescence as relating solely to the economic value of an article without regard to its physical condition seems to serve the purpose admirably. It is therefore important to find a correct measure of the economic value. At a previous Production Meeting of the Society it was said that labor savings only are taken into account by the tool engineer in determining how soon a given piece of equipment will pay for itself. If this procedure is general, is it not possible that our method of determining economic value is obsolete?

We have fully automatic machines which require virtually no labor. Labor saving alone would never justify replacing such equipment, but we know that automatic machines become obsolete. When labor is the dominant factor in costs, labor saving alone may measure accurately enough the entire economic situation affected by a decision and justify the use of the old procedure. However, when burden is approximately twice the labor cost, as it is today in many industries, it is high time that we give attention to the effect of burden charges and to burden savings.

The correct solution of this problem demands first a change in accounting procedure, so that we get accurate standard costs instead of averaged actual costs. This would result in transferring wastes from factory costs to a "manager's controllable" account, and should show up costs as they can and should be with wastes eliminated.

Correct costs alone will almost automatically distinguish obsolete equipment. Each piece of equipment should stand on its own merits, instead of having facts regarding its operating cost concealed by the application of an average burden rate. Costs can then be compared with those of modern equipment on the same basis.

Any formula in which the net investment is divided by the annual savings will show how soon new equipment can be paid for, but it will do this only when correct amounts are inserted in the formula.

Selling from Next Year's Balance-Sheet

R. E. W. HARRISON[10]:—Having regard to the facts that profitable operation is the objective, and that machine-tool equipment is merely a means to the end, the meaning of the word obsolescence, in so far as machine-tools are concerned, is simply a question of relative earning capacity. In other words, a machine-tool becomes obsolete when its earning capacity is so much below that of a new and later designed tool of the same type that the difference will more than repay the investment required for the new tool. Experience indicates that all other considerations concede first place to that of relative earning power.

Following this line of thought through to a conclusion, it will be agreed that it is sometimes profitable to dispose of relatively new equipment within a very short period, and on the other hand it is sometimes desirable to retain other equipment for as long a time as it will continue to function satisfactorily.

The major problem confronting all progressive ma-

PREPARED FOR — ANALYSIS No. — DATE

PART — OPERATION

Equipment Proposed
Machine
Tooling
Total Investment

Production required per year
Present production per machine per hour
Proposed production per machine per hour
Present number of machines per operator
Proposed number of machines per operator

Present direct labor man hours per year = Production per year / Prod./operator/hour = ——— = hours
Proposed direct labor man hours per year = Production per year / Prod./operator/hour = ——— = hours
Saving in direct labor man hours/year hours
Machine available for other work hours per year.

Present burden hours per year = Production per year / Prod./machine/hour = ——— = hours
Proposed burden hours per year = Production per year / Prod./machine/hour = ——— = hours
Saving in burden hours per year hours

Saving in direct labor per year = hrs. ● per hr.
Saving in burden per year = hrs. ● per hr.
Evaluation of time machine is available for other work = hrs. ● per hr.
Total yearly saving

Time in which equipment will pay for itself = Total Investment / Total yearly saving = ——— = yrs.

Depreciation—Machine % of =
Tooling % of =
Total Annual Depreciation
Annual saving less depreciation =

Net Annual Return on Investment = Annual saving less depreciation / Total investment = ——— = %

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FIG. 1—INVESTMENT-ANALYSIS FORM PRESENTED AS A PROPOSAL FOR THE PURCHASE OF MACHINE-TOOL EQUIPMENT

The Opposite Side of the Sheet Displays the Time in Which the Equipment Recommended Will Pay for Itself, the Net Annual Return on the Investment Required and the Name of the Company Submitting the Estimate

[9] Vice-president and general manager, The Oesterlein Machine Co., Cincinnati.

[10] Chief engineer, Cincinnati Grinders, Inc., Cincinnati.

chine-tool manufacturers is the invention and development of improved tools and methods which will make it more profitable for machine-tool users to install new equipment than to continue to use the old.

I take it as a compliment to the progressiveness of the machine-tool industry when the authors state that the factor of obsolescence is now greater than the factor of depreciation in production machines.

The Cincinnati Milling Machine Co. and the company with which I am connected has made a practice of presenting its case for the replacement of obsolete equipment in the form of a balance sheet, as shown by Fig. 1. The information necessary to compute this return on investment is called for on a separate blank prior to submitting the proposal.

This practice indicates the desire of the machine-tool supplier to offer his equipment on the basis of improved earning capacity.

It was only after a very careful study of the three formulas evolved by the SKF company, the A.S.M.E. and the *American Machinist* that these forms were put into use. The enthusiasm with which this method of presentation has been received is a convincing indication that thought along these lines was somewhat overdue.

I readily agree that it is a misleading accounting policy to use a flat overhead charge against all machines, and I believe that the thought holds in the most progressive and successful quarters that a differential overhead based on the capital invested in the individual piece of equipment under consideration is the only accurate way in which a true picture of the case can be arrived at.

Unstable Products Require Flexible Tools

The question of stability of product might perhaps better be stated as instability of product, as the automotive branch of mechanical engineering has led the world in the thought that frequent mechanical improvements in design result in increased sales and greater revenue.

This progressive policy has in turn brought about an unfavorable regard for the single-purpose machine. Cases can be cited in which heavy investments in single-purpose machines have resulted in stagnation in product design, followed by diminished sales and financial difficulties.

Realization that inflexible equipment is unprofitable to a company having a progressive design policy has been an influence in favor of standard flexible machine-tool equipment requiring a greater investment in fixtures than was formerly needed.

Resulting from this line of thought also has been the production, by the machine-tool manufacturers, of unit-type machines which can be built up into a variety of combinations to suit the users' special requirements. However, very careful managerial balancing of merits is called for to determine which particular type of equipment is most suited for the volume of production under consideration, as well as the probable stability of the design for which the fixtures are required.

Analytical study of the costs of manufacture with the best modern equipment indicates that two of the means by which greatest economies can be effected are by provision of hopper feeds and the application of automatic sizing devices. These relieve the operator, to a very large extent, from individual tool supervision, and lead to greater efficiency as measured in the value of the product over machine-man-hours, with a proportionate reduction in direct labor cost per unit piece produced.

No formula can take the place of keen managerial perception and uptodate knowledge of the available facilities for economical manufacture. The formula is simply a vehicle whereby the case for obsoleting an old tool can be made clear on the basis of dollars and cents.

What seems to me to be the best available plan is the five-year scheme which is now used by the equipment department of the Westinghouse Electric and Manufacturing Co.[11] This policy automatically provides for keeping up the earning capacity of the machine-tool equipment. While the scheme is absolutely sound, it cannot take into account phenomenal improvements in machine-tool practice, and this is where the horse sense, mentioned by the authors, comes in.

I believe that the future advance of both the automotive and machine-tool industries is along the lines of the more or less special, highly productive machine with sufficient flexibility built into its design to enable it to be rebuilt, at moderate cost, to take care of reasonable changes in the design of the customer's product.

Experience in the economics of the situation indicates that maximum progress can be made along the lines of a compromise between the single-purpose and the general-purpose type of equipment, as in this way the investment in new equipment is given the longest useful life.

CHAIRMAN E. F. DUBRUL[12]—Every year more men are becoming dissatisfied with the Simple Simon rule of average burden, which leads to difficulties like those of the hiker who came to the bank of a creek and asked a native how deep was the creek. The native answered, "It averages two feet." The traveler started to wade across but drowned in the middle.

The method of averaging makes shop management too difficult. The financial management often says that it wants 15, 20 or 30 per cent returns on its total investment. But too often it expects the shop management to produce all of that return by earning 100 to 200 per cent per year on the machine-tool part of the investment; and, worse still, the financial department then limits the shop to ridiculously small appropriations for machine-tools with which to make this return.

A Standardized Accounting System

The National Machine Tool Builders' Association has an active cost-accounting service department. We find that analyzing the burden down to the smallest practicable economic elements, as advocated by the authors of this paper, reveals astonishing facts which the management of a factory could never perceive from averages. The average method of distributing burden is a most effective device for concealing facts which the management should know.

Shop men seem to shy away from accounting figures, which appear to them to be difficult and uninteresting. Figures seem to lack the life that is in a picture, and yet life and action are vividly present in a good set of cost figures. A works manager walks around and sees the workmen busily engaged on the materials in process; but too often he fails to recognize the human beings, the goods and the dollars that go to make up an accounting statement.

There is no one place in a large factory, or even in a

[11] See *American Machinist*, June 26, 1930, p. 1013.

[12] General manager, National Machine Tool Builders' Association, Cincinnati.

small one, where the manager can stand and physically observe all of the things that are going on or find the exact relationship of one thing to another. But in the accounting statements he can see them all at once and weigh one factor against another accurately and unfailingly. Good accounting puts in his hand an instrument which will enable him to see unerringly and take command of all the essential facts of his business, including profit control, labor control, financial control, inventory turnover, expense control and equipment cost.

Only on a good accounting statement can all these features of the business be seen at once. The knowledge, judgment and ability of any shop manager are certain to be improved if he places himself in this one spot from which the condition of his business can be studied. If the accountants themselves really saw that

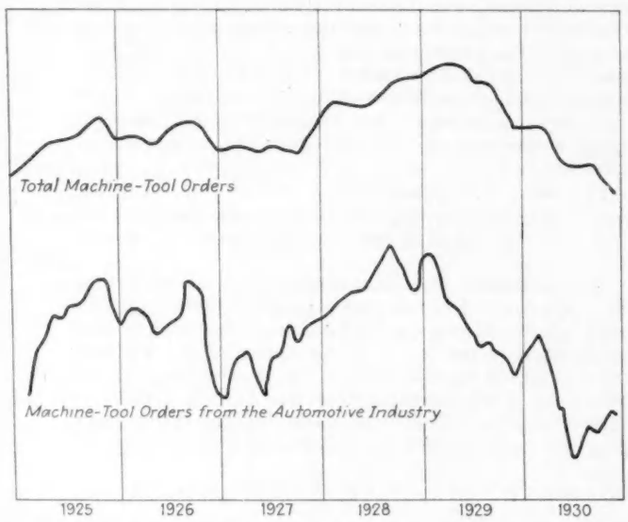

FIG. 2—CURVES OF MACHINE-TOOL PURCHASES FOR SIX YEARS

the accounts are a human story, shop men would not shy off when formulas are presented from which the salient facts can be visualized.

No one has yet made a study to determine which of the several formulas for determining obsolescence is the most practical. Research work is needed on this question. A formula may contain too many factors of minor importance. If we put engineering brains behind the use of a good formula, questions of obsolescence would be solved and the shop men could interpret to the financial men their requests for equipment in terms of dollars and cents.

It has been well said that a safe practice is to buy new machinery only when it costs more not to buy it. To have a statement accepted, the premises of the reasoning must be accepted by those to whom it is presented. Cooperation between the engineering societies and the equipment manufacturers' associations would help to make the use of equipment formulas more than mental gymnastics, which managers now are inclined to consider entirely unnecessary. Let us get together on this question and, having worked out a rational and practicable formula, let us show management how its use will protect profits.

[13] General sales manager, Cincinnati Milling Machine Co., Cincinnati.

[14] See S.A.E. JOURNAL, March, 1931, p. 378.

FREDERICK B. HEITKAMP[13]:—The authors of this paper have suggested that machine-tool manufacturers should guarantee the production on their machines. We have gone to the mat many times on that question, and in that connection I am glad that Professor Boston presented his paper on power required for drilling[14] at this session. The machinability of the metal is only one of many variables that prevents reputable machine-tool manufacturers from guaranteeing their production. The best guarantee is to deal with reputable manufacturers whose reputations are at stake and who will see to it that you get proper performance from the machines that are installed.

Fig. 2 will serve as the text of a plea to the automotive industry to stabilize its machine-tool buying. The upper curve represents the total orders received by the machine-tool industry and the lower represents the machine-tool orders received from the automotive industry. This lower curve contains extremely violent fluctuations. I suggest that automotive manufacturers apply the replacement formulas to some of the obsolete machine-tools and have them replaced during the slack period, then the machine-tool makers will be prepared to furnish the more special high-production equipment promptly when they are demanded.

Cooperation by the tool users is necessary to secure an analysis of return on investment such as is shown in Fig. 1. Accurate information is necessary to show the large potential profits which may be available. Finally, a willingness to buy on the basis of a reasonable return, when this is shown by the machine-tool builders, is fundamental.

JOHN W. BRUSSEL:—Many obsolete machines are inherited. Following is a specific case: One department carries an expense of $350 per month for supervision and $1,713 for depreciation on old machinery bought 12 to 15 years ago. Is that depreciation chargeable to the production man or to the management? Certain machines work only two or three hours per month because of lack of orders and carry a depreciation charge of $187 per month while the direct labor consumed is only $6 per month. Yet this depreciation is entered as manufacturing fixed expense. Production men should study the accounting and find out how production expenses are computed. I have been studying the question for many years and find that production men are charged unfairly with many expenses over which they have no control. The sooner that question can be cleared up with the higher executives, the better off all production executives will be.

Short Time Upsets Cost Figures

CHAIRMAN DUBRUL:—I have much sympathy for production men who are being victimized by accounting methods. In every line of business, the shop man is required to make up for much inefficiency on the part of management.

We put our fingers on that spot in setting up the standard accounting system for the machine-tool builders' association. We assumed one-shift operation to be 48 hr. per week for 50 weeks per year. A careful survey of the records of the machine-tool industry for 11 years indicated average operation amounting to only 60 per cent of this time. During 12 years the industry has had two beautiful peaks during which one month's shipments just about equalled the one-

(*Concluded on p. 476*)

A Comparison of Methods for Determining Gum Contents of Gasolines

Discussion of Annual Meeting Paper[1] by Oscar C. Bridgeman[2] and Elizabeth W. Aldrich[3]

WIDESPREAD adoption of crude-oil cracking processes to provide an adequate supply of gasoline of high antiknock value has introduced the gum problem. The solution of this depends upon the development of a satisfactory method for determining the true gum-content of a fuel at the time of test and for predicting the content of a gasoline stored for a given time under specified conditions, and upon the correlation of data obtained by these methods with the results of engine tests.

Several methods proposed and used for determining the gum content of gasolines are described and data obtained by means of them are compared. Because published data from these methods do not establish that any of them or modifications of them are satisfactory and reproducible, the Bureau of Standards, with the cooperation of the Army Air Corps, undertook an investigation of test methods, as part of an extensive program for the study of the gumming characteristics of gasolines, with the purpose of applying to them a rational criterion for their accuracy and to amass further information regarding their reproducibility.

The paper is a report on this work. In the preliminary tests, data were secured by three methods on 20 gasolines and blends, and these data are compared, no relationship between the results being apparent. As time required for evaporation is a variable, tests were made with the air-jet method for accelerated evaporation and the comparative data are presented in tables and charts. Further tests were made with different volumes of gasoline and in inert atmospheres of carbon dioxide and nitrogen. More convenient apparatus for evaporating the samples under a nitrogen jet in a nitrogen oven is under construction.

The paper concludes with an analysis of the problem of determining the gum content of a gasoline and sets forth the three styles of a logical mode of attacking it.

Two methods for determining gum content that were not covered in the paper received favorable comment in the discussion. These were the steam-oven method, presented by a representative of the Vacuum Oil Co., and a modification of the air-jet method, reported by a representative of the Standard Oil Development Co., which gives flash distillation by dropping the gasoline into the hot dish drop by drop.

J. C. MOLITOR[4]:—Conclusions presented in this paper are in entire accord with those arrived at in the research work of the Vacuum Oil Co. in that values by different methods do not agree. The authors, however, have given no data obtained by one of the important methods, the steam-oven method, and it seems of interest to present some comparative data on a group of gasolines as secured by the air-jet and steam-oven methods.

The technique used by us in the air-jet method is essentially the same as that used at the Bureau of Standards except that the rate of air-flow was always near the maximum that could be employed without blowing some of the gasoline out of the dish. The steam-oven method employed is a modified form of that proposed by Cooke[5]. The oven was maintained at 165 deg. cent. (329 deg. fahr.) by a thermostatically controlled external electrical heating-unit. Dry steam was passed through the oven. Then, 50 cc. of gasoline was transferred to a glass dish of about 75-cc. capacity by means of a pipette. The dish was then placed in the oven for 16 hr., which time was found sufficient to bring the gum deposited to constant weight. The dishes were then removed, placed in a desiccator for 30 min. and weighed to 0.1 mg. Chemical cleanliness of the apparatus was rigorously maintained and extreme care was exercised in the determinations made by both methods.

Data were obtained by each method from 40 gasolines of various gum contents. The results are presented in Table 1, herewith.

Three things are apparent from these comparative data:

(1) The results by the steam-oven method are very much lower than those obtained by the air-jet method.

(2) There appears to be no definite relation between the results by the two methods, but the values by the steam-oven method are roughly 35 per cent of those obtained by the air-jet method.

(3) Each method is satisfactorily reproducible, the steam-oven method having a slight advantage in that respect.

Data Secured on 50-Per-Cent Blends

Data were also obtained by both methods upon several gasolines and their 50-per-cent blends. The 50-per-cent samples were prepared by diluting a very high-gum-content gasoline with an equal volume of a gum-free gasoline. The results are shown in Table 2 herewith. Each sample marked *B* is a 50-per-cent blend of the gasoline immediately above it.

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[1] Published in the S.A.E. JOURNAL for February, 1931, p. 191. An abstract of the paper is presented herewith, together with a brief abstract of the discussion.

[2] S.M.S.A.E.—Research associate, Bureau of Standards, City of Washington.

[3] Junior chemist, Bureau of Standards, City of Washington.

[4] Junior chemist, Vacuum Oil Co., Paulsboro, N. J.

[5] See Bureau of Mines Reports of Investigations No. 2686, 1925

A very interesting point can be brought out by referring to Fig. 6 of the paper. Here the zero intercept, a_1 of equation (1), represents the gum content of the sample in question corresponding to instantaneous evaporation. This intercept a_1, will also represent the true gum content of the gasoline if the effects of the variables such as temperature and atmosphere are sufficiently convergent to be extrapolated out.

J. C. MOLITOR

From the evidence presented in Fig. 6 we note that there seems to be a general relation with respect to the zero intercept a_1; namely, a_1 is two-thirds of the air-jet value obtained when 50 cc. of the sample is evaporated.

Applying this factor 2/3 to get the zero intercept of each of the 40 gasolines in Table 1 from the air-jet value at 50 cc., we find this value, which presumably is true gum-content, to be much higher in each case than the steam-oven value for the same gasoline. It follows that the expected convergence of the variables does not occur, and the values obtained at the zero intercept do not represent true gum-content values when obtained by the air-jet method. The data given by Bridgeman and Aldrich, together with those of Tables 1 and 2, tend to show that the steam-oven method comes nearer to giving true gum-content values than any of the methods presented in the paper.

[6] M.S.A.E.—In charge of knock-testing control, Standard Oil Development Co., New York City.

[7] See S.A.E. JOURNAL, January, 1930, p. 31.

[8] M.S.A.E.—Assistant to vice-president in charge of manufacturing, head of development and patent department and in charge of research, Standard Oil Co. of Indiana, Chicago.

TABLE 1—COMPARATIVE DATA BY AIR-JET AND STEAM-OVEN METHODS, MG. PER 100 CC.

Gasoline Number	Air-Jet[a] Method	Steam-Oven[b] Method
1	212, 210	75, 72
2	194, 188	106, 109
3[c]	160, 161	37, 37
4	151, 160	54, 53
5	152, 139	84, 80
6	146, 144	72, 76
7[c]	133, 121	36, 36
8	123, 115	33, 32
9[c]	122, 115	38, 39
10[c]	115, 108	33, 35
11[c]	104, 113	51, 44
12[c]	101, 94	30, 25
13	98, 96	47, 46
14[c]	96, 91	68, 68
15	95, 93	27, 26
16[c]	93, 91	14, 14
17	90, 86, 89	40, 45, 42
18	92, 86	24, 20
19	88, 82	34, 36
20	86, 81	17, 10
21	78, 72	17, 17
22	72, 69	31, 33
23	67, 65	15, 16
24	67, 61	25, 24
25	{51, 58, 53} {56, 53, 52}	{27, 23, 24} {25, 25, 24}
26[c]	55, 56	13, 15
27	52, 50	10, 10
28	50, 51	21
29[c]	49, 46	16, 16
30[c]	49, 51	13, 13
31[c]	46, 41	15, 15
32[c]	44, 38	10, 9
33	41, 41	9, 9
34	42, 42	16, 16
35	42, 38	14, 16
36[c]	38, 36	21, 23
37	29, 28	9, 10
38	20, 19	4, 4
39	12, 11	4, 5
40	10, 10	4, 4

[a] Average deviation from mean values, 2 mg.
[b] Average deviation from mean values, 1 mg.
[c] These values appear also in Table 2.

TABLE 2—DATA ON 50-PER-CENT BLENDS

Gasoline Number	Air-Jet Method Mg. per 100 Cc.	Air-Jet Method Percentage	Steam-Oven Method Mg. per 100 Cc.	Steam-Oven Method Percentage
1	160, 161		37, 37	
1*B*	91, 93	57	14, 14	38
2	133, 121		36, 36	
2*B*	55, 56	44	13, 15	39
3	122, 115		38, 39	
3*B*	49, 51	42	13, 13	34
4	115, 108		33, 35	
4*B*	49, 46	43	16, 16	47
5	113, 104		51, 44	
5*B*	41, 46	40	15, 15	32
6	101, 94		30, 25	
6*B*	44, 38	42	10, 9	35
7	96, 91		68, 68	
7*B*	36, 38	40	21, 23	32

New Method Eliminates Time Element

A. E. BECKER[9]:—The gum problem is very well stated at the beginning of this paper. The customer is always interested in the gum content of the gasoline at the time it enters the carbureter, and in some cases also in the content at the time it enters the storage tank. What is needed is a reproducible test that can be used by everyone and that will give the actual gum content of the gasoline at the time of the test.

O. C. BRIDGEMAN

Reference was made in the present paper to a paper by Hunn, Fischer and Blackwood[7]. H. G. M. Fischer, one of the authors of that paper, has modified the air-jet method to virtually eliminate the variation due to the time of evaporation by introducing the gasoline into the dish drop by drop while a current of air is blown into it. In this way, there is never more than 1 or 2 cc. of gasoline in the dish at any one time. Furthermore, creeping can be entirely eliminated. This modification seems to hold promise in the development of the air-jet method.

R. E. WILSON[8]:—It is unfortunate that it has been deemed necessary in such a careful study of methods of determining gum content to prove once more that

the copper-dish method is practically worthless. A tremendous amount of time has been wasted in half-a-dozen laboratories, every one of which proves this point conclusively; yet everyone who begins such a study feels that this approach is necessary. There is also cause for regret that the steam-oven method, covered in Mr. Molitor's discussion, was omitted from this study.

Why do the authors take the position that no satisfactory method now exists for the determination of gum content? The steam-oven method, possibly with some slight modifications, has been found satisfactory in our experience.

I agree that it is very important to distinguish clearly between actual gum and potential gum. Any method which involves evaporation in the presence of air and requires a considerable time is objectionable, as it includes both kinds of gum. The method mentioned by Dr. Becker, which amounts to instantaneous or flash distillation, seems the most logical one if the steam-oven method must be abandoned. Distillation of gasoline in an engine manifold is essentially flash distillation, as there is no body of liquid that is being evaporated slowly in the presence of air and practically no chance for oxidation.

Steam-Oven and Flash Methods Check

My opinion, which the few experiments that we have made has tended to confirm, is that the results obtained in flash distillation correspond closely to those obtained by the steam-oven method. It seems that a comparison between these two methods should be more significant than any comparison with the obsolete copper-dish test.

For measuring potential gum, our laboratories have continued their favorable experience with the method described by Voorhees and Eisinger[9] of determining the induction period. This involves making a curve representing the rate of oxygen absorption on the basis of time and shows that stable gasolines in contact with oxygen under pressure, even at high temperatures, remain stable for many hours or days before they suddenly begin to absorb oxygen and form gum at a rapid rate, whereas unstable gasolines may begin to oxidize rapidly after only 60 min. at high temperature.

R. E. WILSON

We have found definitely that these induction periods are measurably parallel with behavior in storage, and that stored samples which are tested show successively shorter induction periods. When the point is reached at which the induction period is very short, further storage of the gasoline is found to result in large quantities of actual gum.

O. C. BRIDGEMAN:—The statement in the paper was not that no method for ascertaining the amount of gum is satisfactory but that no method has been proved to be satisfactory. I should be much interested to know if Dr. Wilson has proof that the steam-oven method has been proved to indicate satisfactorily the gum deposition in the engine.

DR. WILSON:—We have obtained a good degree of parallelism between gum content by the glass-dish method and gum deposition in the engine. Exact parallelism will not be obtained with engine tests of any sort, but I consider the results that we have obtained to be very satisfactory. The fact that results given by the steam-oven method are lower than by any other seems to show that other methods include a substantial amount of potential gum along with the actual gum in which we are mainly interested.

DR. BRIDGEMAN:—Is 300 deg. fahr. the oven temperature used?

DR. WILSON:—I think that it is.

DR. BRIDGEMAN:—Has Mr. Molitor any information as to whether or not the gum content per 100 cc. by the steam-oven method varies with the volume evaporated?

MR. MOLITOR:—We have conducted some investigation as to that which indicates that the steam-oven values do change in a similar way to the changes observed with the air-jet values; however, the change is not so great, presumably because of the lower values obtained by the steam-oven method.

Test Should Foretell Deposition in Engine

DR. BRIDGEMAN:—Any change such as that indicates that steam-oven values do not represent the true gum-content. It looks as though the true gum-content is some lower value. The ultimate criterion is that a test shall reproduce the deposition in the engine. There is no evidence that the lowest value is the one which corresponds to that.

True gum-content is postulated in this paper as the basis for such a method. This is a characteristic of the gasoline and is independent of the conditions of the test, so that it should serve as a basic method for developing a test which should be significant as to the amount of gum that will be deposited in the engine.

MR. MOLITOR:—The improved air-jet method of Dr. Fischer, mentioned by Dr. Becker, has been tried in our laboratory. We have concluded that the drip method is not an improvement over the usual air-jet method as used by us.

CHAIRMAN J. B. MACAULEY[10]:—Whether or not the lowest value is the one that represents most accurately the results in an engine is still an open question, as Dr. Bridgeman says. Off hand, it appears that flash distillation, such as is used in Dr. Fischer's modified method, should approximate engine conditions more closely than some of the methods which give lower values. It seems that this modification of the air-jet method should be investigated further.

[9] See American Petroleum Institute Bulletin, vol. 10, sec. 2, 1929, p. 169.

[10] M.S.A.E.—Chief engineer, Chrysler Corp., Detroit.

Development of
Drop-Center Rims

Annual Meeting Paper

By Charles S. Ash[1]

HAVING particular reference to passenger-cars, the rim industry has had a somewhat diversified experience. Years ago, in the infancy of the automobile, the wheels were very large in diameter and the rims quite narrow in section. The section used was almost universally known as the plain clincher type of rim. This was an endless rim adapted to use a tire having a soft or pliable bead. The tire was stretched or buttonholed over the rim flange in case of mounting and removal. This rim was a very suitable construction so far as wheels and rims are concerned, but did not work out so well in connection with tires. The main trouble, I believe, was with rim-cuts around the edge of the rim.

The advent of the straight-side tire, which was supposed to eliminate rim-cuts and provide a more reliable bead construction, necessitated a rim of complementary design. This straight-side tire had a more or less rigid bead construction; so it could not be applied to the rim over the top of the rim flanges.

It was necessary to provide a rim with detachable side-flanges or rims that were split and could be collapsed for tire removal.

This type of construction has been very popular and practical for a number of years; however, during the last few years, the trend has been toward smaller rim-diameters and tires of larger cross-section. At the same time the tire diameter has been somewhat decreased to bring the car body closer to the ground, or to lower the center of gravity. In fact, in some cases the rim diameter has been small enough to handicap the present construction.

Referring to passenger-cars, the author mentions the plain clincher-type of rim first used, and the rim with detachable side-flanges or that was collapsible which followed the advent of the straight-side tire. The difficulties incident to the split straight-side rim and the "Q.D." rim brought about consideration of the drop-center-rim construction, which is described. The advantages of drop-center rims are then enumerated.

Definition of "Drop-Center Rim"

The split straight-side rim is more difficult to collapse and the side ring of what is known as the "Q.D." rim is somewhat difficult to apply and remove. These conditions, as well as features hereinafter described, have brought about the consideration of the drop-center-rim construction.

The term "drop-center rim" has been applied to a rim having a much different cross-section than either the plain clincher or the straight-side rims mentioned. The drop-center rim is an endless rim, both side flanges being integral. The center portion of the rim between the two tire-bead seats is depressed or rolled smaller in diameter to provide what is termed a "well." This well is so formed in proportion to the side flanges as to facilitate the mounting and demounting of tires.

In removing the tire from a drop-center rim, the tube is first deflated and one or two tire-beads are dropped into the well. This allows the beads on the opposite diameter of the tire to be removed over the rim's integral side-flange. The tire change then is made much the same as when using the old plain clincher rim, except that in the case of the drop-center rims a straight-side tire with more or less rigid beads is used.

Many forms of drop-center rims have been proposed and used. The form depends largely on the tire construction, and particularly upon the uses to which the rim must be adapted. The drop-center-rim section has been used for airplane wheels for some time, but this section is somewhat different from the sections proposed for passenger-cars.

The passenger-car drop-center rim has been proposed and used in different sections; but the principle in changing the tire and the use of the rim is the same except that, with one design of rim, it may be possible to remove a tire two beads at a time, while on others it is possible and desirable to remove the tire one bead at a time. It is considered sensible, of course, to arrange the wheel, rim and tire to provide a unit that is most satisfactory to the public.

Advantages of Drop-Center Rims

Drop-center rims give several advantages to the passenger-car designer, such as light peripheral weight, the rim being endless and in one piece, and there are no loose parts to handle and no possibility of distortion. By reason of its shape and design, the drop-center rim is much stronger, because it is endless or

[1] A.S.A.E.—Sales engineer, Kelsey-Hayes Wheel Corp., Detroit.

made in one piece; therefore the rim naturally can be made truer and more nearly round. Consequently, when finally mounted on a car, it will run truer, provide a better balance and should give better tire-life and performance. There may be several details to work out, but the rim should be designed so that it is applicable to any type of wheel and so that the design will be as flexible as possible and still be reliable.

The side-flanges of the rim may be of the conventional type, following the same contour as the flanges of the ordinary flat-base straight-side rims; or they may be of the "curled-in" type, each flange being of tubular section.

The drop-center-rim sections, as they are set-up as a standard today, provide a proportionally greater distance between side flanges than has been used on regular flat-base-type rims. This, in connection with the drop-center portion, tends to provide a little more air capacity in the tire. This fact, in connection with the increasing cross-section of the tire, together with the endless integral-rim construction, assures the rim flanges and the like against distortion in service and the rim will hold its shape permanently. From an engineering viewpoint it seems that drop-center rims, when properly developed, will be a great advantage to the industry.

Controlling Factors in Machine-Tool Obsolescence

(*Concluded from p.* 471)

shift capacity. But the industry had to supply the demands by means of overtime work and double shifts. Perhaps the industry has too much capital invested in the plants that were needed to supply its customers' requirements during these two peaks.

Our system of costs is based on average operation of 130 hr. per month. If a machine does not run 130 hr., that fact is disclosed by the accounts. The management can then investigate to find out why any machine runs short time. This condition is segregated so that a cure can be found for it.

Perhaps the sales department should produce work; perhaps the fault is with the shop management for having bought a machine without definitely knowing whether it was worth while. At any rate, it is necessary to diagnose a disease before it can be cured, and this system gives a diagnosis. Machine-tool builders who use that standard cost-method find out many things by means of it.

Some day the cost of selling and of production engineering will be measured. Nobody knows how much money is wasted in useless production-engineering work for the customers of the machine-tool industry. If wastes such as these can be eliminated, the customers who do not cause that waste will not have to pay for it, as they do now.

I do not like the word "spread" in describing the usual method of handling overhead. One of our German cost accountants calls it "smearing." I think that term is more appropriate, since it represents costs that are smeared carelessly over the products.

I recommend much campaigning among shop men for better cost figures. Do not let the accountant tell you that good costs are too much trouble; poor costs always cost too much. If costs are well figured, they pay for themselves many times in the economies they make possible by revealing the sore spots.

L. A. BLACKBURN:—I have tried to avoid, as much as possible, criticism of the cost-accounting departments. All of the trouble cannot be laid at the cost-accounts' door, because cost accounting has made progress equal to that of anything except the manufacturing itself. We production men are to blame because we have not fought for the information that is really needed and showed the management that these things are big items in the profit and loss column.

Fraternal Regard of Section Members

Section
We will have to elect five members to the Nominating Committee who will say who are going to take the offices of the Section for next year. Nominations are in order for that Committee. One point I want to make is not to nominate anyone you would like to see an officer of the Section next year.
A. B. Smith: I nominate Mr. Jones.
C. D. Jones: I nominate Mr. Smith.
Chairman:
take time now to
From the notes of an actual Section meeting.

Scientific Inspection Reduces Motorcoach Operating Costs

Discussion of H. B. Hewitt's Transportation Meeting Paper[1]

THIS PAPER is both a plea to manufacturers of commercial vehicles and their units to cooperate with operators in scientific study of maintenance problems and an exposition of inspection methods that have reduced the operating costs of a large system of city-type motorcoaches.

The author comments upon the large expenditures of the manufacturers of automotive equipment upon research laboratories for the improvement of the quality and reduction of the cost of vehicles. He concludes with the suggestion that the diversion of some part of these facilities to the solution of maintenance problems will reduce the cost of operating commercial vehicles sufficiently in some cases to enable the operators to purchase additional vehicles. He urges the lifting of the ban against furnishing factory blueprints and working drawings to maintenance men and the establishment of standard practices for repair shops.

Inspection for the detection of errors should be based on a knowledge of facts obtained by scientific research, and data so obtained should be preserved under one form so that a standard practice can be established. Maintenance inspectors should be highly specialized, properly instructed in standard-practice procedure, and know labor and material costs.

The author asserts that the correct method for ascertaining the time to make repairs, adjustments or replacements to commercial vehicles should be based on condition of the vehicles rather than upon time or mileage, and that men developed as diagnosticians rather than inspectors should determine the extent of repairs to be made and the time to make them. He then describes the maintenance methods followed by the operating organization he represents and gives charts and tables showing substantial increases between inspection periods and large reductions in mechanical failures per mile operated.

Gasoline-mechanical and gasoline-electric drives are compared in the discussion, and the utilization of watt-hour meters for determining what the desirable period of inspection is by calculating the mileage in terms of kilowatt-hour output of the generator is explained. The subject of maintenance in operation of standards of clearances and tolerances set by motor-vehicle manufacturers is also mentioned.

CHAIRMAN F. C. HORNER[2]:—I think that most members of the audience will be particularly interested in discussing Mr. Hewitt's paper, due to the fact that the majority of the vehicles he operates are gasoline-electric vehicles. There is a wide divergence of opinion regarding the merits of the mechanically driven and the gasoline-electric-driven vehicles.

This question regarding inspection is of profound importance to operators. Quoting the old adage "a stitch in time saves nine," if the operators are right on top of the small troubles, these do not grow into big troubles.

A. J. SCAIFE[3]:—Referring to the gasoline-mechanical versus the gasoline-electric drive, there are many men in the business who are partial to a certain type of operation. If they have been trained in steam-railroad operation, they prefer steam for motive power. If one could build a steam-operated motorcoach, he could sell it to the railroads. Others have been trained in the electric-railway business and they prefer electricity as motive power. This is natural. But the men who have had no training in either of the foregoing systems seem to prefer the gasoline internal-combustion engine with a complete mechanical drive.

Gasoline-Electric-Driven Vehicles

I am trying to visualize what results would be obtained from operating a fleet of gasoline-electric-driven motorcoaches outside of the field of electric-railway companies. I wonder whether a connection still exists that makes the electric-railway executives partial to the gasoline-electric-driven vehicles. Such executives are in the electric-railway business, and not in the transportation business primarily. Aside from the electric-railway companies, does anyone operate gasoline-electric-driven vericles?

A. H. GOSSARD[4]:—I cannot say whether gasoline-electric vehicles are operated by any other than the electric-railway companies, but in 41 cities our subsidiary companies are furnishing street-railway transportation and, in 16 cities in which they furnish motorcoach transportation, no gasoline-electric vehicles are used. The executives of these subsidiary companies are free to buy whatever motorcoach equipment they prefer. If there were a tendency to lean that way, it seems that there would be some gasoline-electric vehicles in these fleets; but there are none.

C. W. STOCKS[5]:—In reference to Mr. Scaife's question the answer is "no."

ADRIAN HUGHES, JR.[6]:—I believe that Mr. Hewitt's gasoline-electric motorcoaches are equipped with watt-hour meters for determining the desirable period of inspection and calculating what the coach is doing as

[1] The paper was printed in the January, 1931, issue of the S.A.E. JOURNAL, beginning on p. 84. The author is engineering assistant to the vice-president in charge of operation for the Mitten Management, Inc., Philadelphia. An abstract of the paper and discussion precedes the text.

[2] M.S.A.E.—Assistant to the vice-president, General Motors Corp., New York City.

[3] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

[4] M.S.A.E.—Manager, automotive department, Middle West Utilities Co., Chicago.

[5] M.S.A.E.—Editor, *Bus Transportation*, McGraw-Hill Publishing Co., New York City.

[6] M.S.A.E.—Superintendent of motorcoach transportation, United Railway & Electric Co. of Baltimore, Baltimore.

to mileage in terms of kilowatt-hour output of the generator. Might it not be an advantage to measure the gasoline consumed by each motorcoach rather than the generator output, which would indicate the condition of the engine and at the same time might give a measure of the power output of the engine and therefore a measure of the desirable inspection period at the same time?

H. B. HEWITT:—The particular advantage of using the watt-hour meter, as we find it, is that the record includes the grades, loads and speeds; that is, the watt-hour is really a unit of work. However, as I tried to indicate in my paper, we are getting away from a definite repair-period and leaving the equipment alone so long as it functions satisfactorily. The watt-hour meter gives us an additional analysis of the individual driver. We have carried that out to such refinement that, if a particular driver on a certain route does not have a record as good as that of some other driver, he is given special instruction. It may be that the desired results can be accomplished by measuring the fuel. If someone will provide us with an accurate fuel-measuring device, that will help; but we have tried several devices and have not had real success.

Extension of Inspection Period

J. F. WINCHESTER[7]:—The extension of the inspection time, as mentioned in Mr. Hewitt's paper, was done, I assume, as the result of experience, largely brought about through improvements as repairs have been made, through having required specifications for motorcoach and other recent purchases, and because of mechanical improvements now incorporated in the later models.

Regarding his mention of the blocking of the exhaust system on Knight engines, we have been led for years to believe that the engine performance improved with the accumulation of carbon; but, as I understand him, that is not true. A point is reached at which it is necessary to remove carbon from the exhaust; otherwise the horsepower is very greatly decreased.

L. V. NEWTON[8]:—One point not yet brought out is that one must have an inspection system regardless of what system he employs. Unless there is an inspection system, one does not know whether the job is all right or all wrong. If dependence is placed on a driver to report whether his vehicle is in good condition, if he is a good driver he will report it and if he is not a good driver the trouble will not be found until the driver has a breakdown on the road. A great aid in maintenance is to have good supervisors, who ride the vehicles and report defects.

MR. WINCHESTER:—I should like to ascertain the status of the owners and users of fleets of vehicles. For example, I should like to compare the operations of the public-service fleets in Newark, N. J.; Camden, N. J.; Philadelphia; and those of the United Railway & Electric Co. of Baltimore. I question whether the same method of determining inspection periods can be applied to the vehicles in these fleets. The gasoline-electric vehicles in Baltimore probably would run 3500 to 4000 miles before needing inspection, but some of the older vehicles in these various fleets seem to me to need inspection at much shorter periods if they are to be safely and efficiently operated.

F. K. GLYNN[9]:—I suggest that everyone read the first few pages of Mr. Hewitt's paper, for in these he has stated as safe and sensible a policy of operation and maintenance as has ever been stated in the same number of words.

M. F. STEINBERGER[10]:—All the efforts of this Session of the 1930 Transportation Meeting seem to be directed toward reduction in maintenance costs. Such reduction leads us to think of net income, which is what we want. But the rail lines are subject to very severe decreases in gross and net revenues. Although I assume that the motor-vehicle lines are also subject to decreases, I wonder why the program of the meeting could not have included reports from some of these motor-vehicle lines which have been able to go through these perilous times with only a small decrease in gross income, so that they might tell us how they did it.

CHAIRMAN HORNER:—It seems to me that a man who is operating motor-vehicle equipment of any kind would be interested in our program for this Session, even though he may be present in a managerial capacity. Such a man certainly should have got some ideas of value if for no other reason than that he could go back to his plant and ask his mechanical or his maintenance men what they were doing along certain lines.

Mr. STEINBERGER:—That is the reason I came here.

CHAIRMAN HORNER:—We feel that we are doing constructive work and we want to hear about all phases of motor-transport operation, whether it be from steam-railroad men, electric-railway men or so-called independents. If everybody contributes something, we can all get the benefit of it.

J. W. COTTRELL[11]:—In Mr. Hewitt's paper he says: "It is not practical to maintain in operation standards of clearances and tolerances set up by motor-vehicle manufacturers." I have in mind one truck-service bulletin which says regarding a certain engine that the connecting-rod clearance is 0.0015 in. and that the engine may be allowed to operate until the clearance is 0.0060 in. Will Mr. Hewitt give an illustration of one such clearance, showing how far beyond the manufacturer's recommendation he goes and what the effect is?

MR. HEWITT:—We could not afford to maintain the standard of tolerances set up by the manufacturers. The extent to which we let the tolerances go depends entirely upon the service. In certain operations we let them go further than we do in long-distance operations. In other words, we want to get all possible service we can before we repair or scrap the vehicle.

[7] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark, N. J.

[8] M.S.A.E.—Byllesby Engineering & Management Corp., Chicago.

[9] M.S.A.E.—Engineer; operation and maintenance of automotive equipment, American Telephone & Telegraph Co., New York City.

[10] M.S.A.E.—Manager of highway transportation, Baltimore & Ohio Railroad Co., Baltimore.

[11] A.S.A.E.—Technical editor, *Commercial Car Journal*, Chilton Class Journal Co., Philadelphia.

Essentials of Motorcoach Maintenance

Discussion of L. V. Newton's Transportation Meeting Paper [1]

AFTER reviewing motorcoach history and outlining the transition period of development the author says that operation and maintenance go hand in hand, but that too much stress is placed on maintenance methods and not enough on operation. He has yet to find a transportation superintendent who makes motorcoach operation a subject of paramount importance, although the manner in which the coach is driven may decide whether that particular coach makes money or loses it.

In the author's opinion, the success of any coach and its freedom from repairs are dependent upon how well the driver knows how to drive it and, secondly, upon systematic lubrication and scheduled maintenance. The selection and training of drivers is a function of the transportation department, and too much stress cannot be laid on these functions and on continuous close supervision so that the department is certain that the vehicles are driven correctly.

The author advocates that all drivers spend two weeks in the repair shop before assuming their duties as operators, and also that drivers' fitness as operators be passed upon by the maintenance department before the drivers assume their positions. He suggests also that, when selecting transportation inspectors or supervisors, men having a mechanical background be chosen so that they may be better qualified to note carelessness and abuse of the vehicles by the driver and to report intelligently on the vehicles' defects when they ride in the motorcoaches.

In conclusion, the author remarks that passengers represent the income of the coach business because, without passengers, there can be no income. Profits are measured by the difference between the income and the expense of operating coaches. The expense, therefore, is equally as important as the income. Consequently, as much effort should be made toward keeping the expense low as in keeping the income high. Eternal vigilance is the price of low-cost maintenance. No maintenance is good unless it is systematic because, otherwise, important items are sure to be overlooked. In the organization of the system it is necessary that the buildings, equipment, men and management all be combined to produce one result; namely, keeping the fleet in running order at minimum cost.

The necessity for careful selection of drivers is stressed in the discussion, and the desirable period elapsing between inspections at stated intervals is debated. The question whether new drivers should be used as helpers in the repair shop following their employment by a given company is discussed also.

CHAIRMAN F. C. HORNER[2]:—The point that stands out in my mind in connection with Mr. Newton's paper is the emphasis he places on the necessity for the careful selection of drivers. The driver of a motor-vehicle can either make or break the company with which he is connected. I agree with Mr. Newton when he says that he would rather have a poor vehicle and a good driver than a good vehicle and a poor driver. This directly affects revenue when in business in the motor-transport field. It may not be quite so apparent when one is using motor transport more or less as a sideline; for example, as in some of the large oil companies, grocery companies, and others. Factors affecting revenue may not be so apparent in such operations, but they exist and they cost money just the same. When engaged in motor-transport as a business, if consideration is not given to the factors mentioned, it may ultimately mean disaster.

J. F. WINCHESTER[3]:—Mr. Newton emphasized the necessity for careful drivers. Mr. Horner also emphasizes the need for reliable drivers if profits are made in motorcoach operations. Mr. Newton was associated for a long time with the oil industry and it was there that he learned how to train the drivers. We in the oil industry have always endeavored to obtain very careful drivers, because they not only have to operate the vehicle but in many instances they must also do sales work, this being a line of work which requires a specialized ability that only the most intelligent type of man possesses.

M. C. HORINE[4]:—Will Mr. Newton state the reasons why he prefers preventive to remedial maintenance?

Reasons for Preventive Maintenance

L. V. NEWTON:—Assuming that we have a good inspection system and that we are looking for trouble at stated intervals, it makes little difference whether we inspect after a 1000 or a 2000-mile period. At some periodic interval, depending upon some recording instrument or on a time basis, the owner is going to inspect each vehicle. The only reason for this is to keep the vehicle from breaking down on the road, and preventive maintenance means that an owner will make repairs before that event occurs. This avoids coach repairs which inconvenience the patrons and are not economic. Take for example an air-compressor for long-distance operation and assume that it is likely to begin to fail after 35,000 miles of operation of the vehicle. With that thought in mind it is much better to change that air-compressor before the point is reached at which it will not maintain the air pressure than it is to wait until the compressor fails and then repair it.

H. B. HEWITT[5]:—Scientific analysis sums up my viewpoint in this matter. With regard to whether to take a unit out or to repair it on a mileage basis, we feel that considerable life is left in such units as might be taken out, and to reduce some of these costs we have

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[1] The paper was printed in the January, 1931, issue of the S.A.E. JOURNAL, beginning on p. 89. The author is a Member and is connected with the Byllesby Engineering & Management Corp., Chicago. An abstract of the paper and discussion precedes the text.

[2] M.S.A.E.—Assistant to the vice-president, General Motors Corp., New York City.

[3] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark, N. J.

[4] M.S.A.E.—Sales promotion manager, International Motor Co., Long Island City, N. Y.

[5] Engineering assistant to the vice-president in charge of operation for the Mitten Management, Inc., Philadelphia.

to keep records to the fourth and fifth decimal places.

A specific instance is that of an axle shaft. Three or four years ago if an axle-shaft spline was twisted about 15 deg., it was taken out and replaced by another. Out of curiosity, we left some of these shafts in service and found that they had many thousands of miles of life still left. Today, we leave the shafts in until there is some indication of a crack that eventually will cause failure.

Shop Experience for Drivers

MORSE REW[6]:—As to the point brought out by Mr. Newton that drivers should be given training in a garage for two weeks, I am thoroughly in agreement with him in principle but I have been trying to determine some way of doing this without seriously interfering with maintenance cost.

Our system of maintenance includes the training of men, and we train our own mechanics. They start in at menial work and are given opportunity to become thoroughly acquainted with the equipment. If we should put the drivers into a garage for a two-week training-course, we could not put them to work on anything better than greasing and, in such case, they actually would learn very little about the mechanical equipment. They would have to go into the operating garage. We could not put them into the overhaul shop because that work requires skilled men. For these reasons, I have not been able to work out a practical system of training drivers in the garage. We are trying to do the best we can in another way by familiarizing them with the mechanical equipment of the vehicles while they are students, before they go out as drivers, and then to give them a series of lectures as they become better acquainted with driving.

MR. NEWTON:—I advocate putting new drivers into the repair shop. They can only be used as helpers, and I realize fully that they undoubtedly slow up the work of the good mechanics to whom they are assigned as helpers. But I believe that the two weeks during which they are assigned as helpers will be amply repaid, because a new driver standing beside a good mechanic and watching him work for two weeks will become familiar to some extent with the vehicle that the new driver will handle later.

MR. REW:—Is the new driver paid for time spent in the garage?

MR. NEWTON:—He must be paid, and this is an out-and-out expense. It is training experience, and there is no way in which it can be made productive.

ADRIAN HUGHES, JR.[7]:—Do you plan to shift these men from one type of work to another while they are in the garage?

MR. NEWTON:—We advocate having them work all over the shop so that they have opportunity to learn as much as possible in a short time.

MR. REW:—I understand, then, that while these new men are watching the mechanics work, you pay them as low a wage as possible.

MR. NEWTON:—Yes, and we get as much work from them as we can.

JOSEPH HUSSON[8]:—My experience with truck operations leads me to say that, in regard to Mr. Newton's advocacy of putting new drivers into a garage for two weeks, I would favor the plan of having the drivers do the driving and the mechanics do the mechanical work. I do not favor having the drivers work on any mechanical parts of the vehicle.

O. M. BREDE[9]:—In defense of Mr. Newton's attitude on mechanical education for drivers, many of the motor-truck and motorcoach troubles that occur on the highway are caused by lack of mechanical knowledge on the part of the driver. When Mr. Newton spoke of mechanical education for drivers, in my opinion he did not mean to make mechanics out of drivers so that, when something happens to the vehicle on the road, the driver will attempt to repair it. What he did have in mind, I believe, was to give these new drivers sufficient mechanical knowledge of the vehicle so that, when trouble occurs on the road, the driver will know the proper thing to do; whether to stop at the curb and telephone for a tow-in outfit or for a mechanic, or to continue operating the vehicle to the end of the run or to the nearest garage.

Perhaps our greatest problem in maintenance today is one of education. Organization, from the manufacturer's viewpoint, feels that this is true. Education of drivers along the lines mentioned by Mr. Newton will, we are sure, result in a lowering of maintenance cost per mile.

MR. NEWTON:—I agree with what Mr. Brede has said. Most of our motorcoach drivers are in uniform; obviously, the drivers cannot get down and do mechanical work without at least ruining their uniforms. On certain long-distance runs, they have to change tires occasionally. This seems like a simple matter, but the majority of drivers are educated in regard to how to set a jack under a coach and how to change a tire; otherwise, they do not know how to do it and do it quickly.

Suppose the case of a man who has spent many years in running a street-car, and who knows nothing about a motorcoach. He is pulled off of a street-car platform, and an attempt is made to convert him into a motorcoach driver. He may or may not know an automobile or a motorcoach intimately. He may own an automobile, but he may not know anything about it mechanically, such as what happens when the clutch slips, what the inside of a clutch looks like or what happens when he jams his brakes on and skids the wheels, and he may not realize what happens to wheel-bearings when a wheel skids up against a curbstone. These are matters that we may be able to teach him during the short time that he is employed in the repair shop. The insurance we take out by having new drivers work for a short period in our repair shops seems to me to be money well spent. But do not get the idea that we are trying to make mechanics out of these men. We are trying to train them to be good drivers.

[6] Superintendent, motorcoach department, Cleveland Railway Co., Cleveland.

[7] M.S.A.E.—Superintendent of motorcoach transportation, United Railways & Electric Co. of Baltimore, Baltimore.

[8] Transportation engineer, Vacuum Oil Co., New York City.

[9] M.S.A.E.—Director of service, General Motors Truck Co., Pontiac, Mich.

Bearing Loads
on Radial-Engine Crankshafts

By E. S. Taylor[1]

DETERMINATION of the approximate distribution of the loads on the main bearings of radial aircraft-engines, so that the bearings can be correctly proportioned and the stresses in the crankshaft can be more accurately calculated, is the purpose of this investigation.

Six radial-engine crankshafts were tested statically to determine the main-bearing loads. The results of these tests are presented in the form of tables and diagrams. General conclusions are drawn from these results.

A short method of calculating the crankpin-bearing load, which gives results in a convenient form, is included.

IN THE ANALYTICAL determination of the bearing loads on a crankshaft, the first step is to compute the loads on the crankpin bearings. This problem is very much simplified in a radial engine by the fact that the sum of the forces due to the inertia of the pistons, pins and rods of the various cylinders is almost completely balanced by the counterweights on the crankshaft. If we assume that all connecting-rods are centered on the crankpin, it can easily be demonstrated that the shaking forces acting on the engine are harmonics of frequency equal to $N\ (n \pm 1)$, where N is the engine speed, in revolutions per minute, and n is the number of cylinders. For all but the three-cylinder radial engine, these forces are negligible.

A much greater unbalanced force is introduced by the master and link-rod construction commonly used. This force varies with a frequency equal to twice the speed of revolution of the crankshaft. Its magnitude depends on the ratio of the radius of the knuckle-pin circle to the length of the link rod. A general idea of the magnitude of this force may be obtained from its value of approximately 400 lb. for the Wright J-5 engine. This is in the neighborhood of 5 per cent of the total force due to inertia acting on the crankpin. The excess weight of the small end of the master rod over the small end of the link rods on this engine causes an unbalanced force of approximately 100 lb., or about 1 per cent of the total inertia force. For the purpose of figuring bearing loads or crankshaft stresses these quantities are negligible.

Assuming that the inertia forces are completely balanced by the counterweights, it is possible to consider the gas forces only in figuring the values of the crankpin-bearing loads. The constant force due to the inertia

[1] Assistant professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

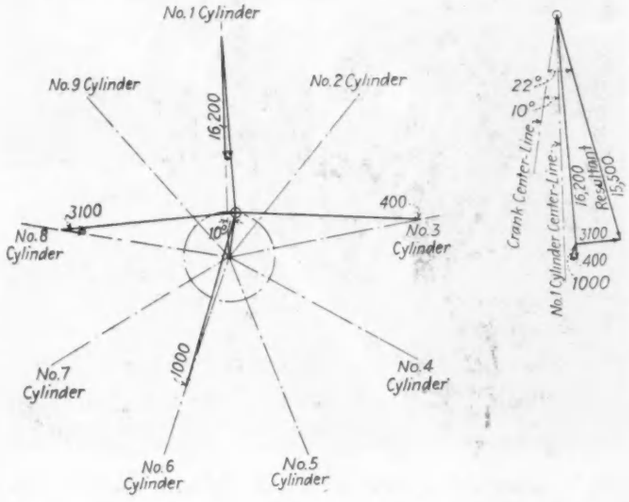


FIG. 1—RESOLUTION OF GAS FORCES ACTING ON CRANKPIN AT AN ANGLE OF 10 DEG.

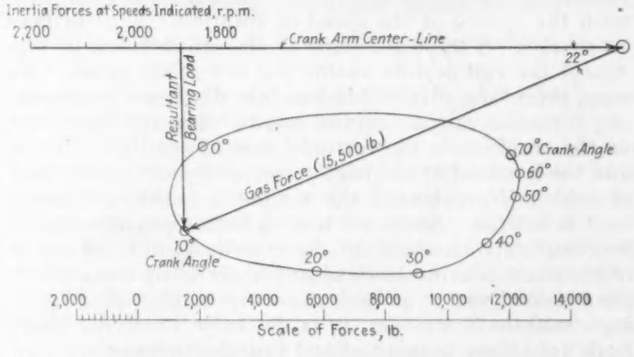
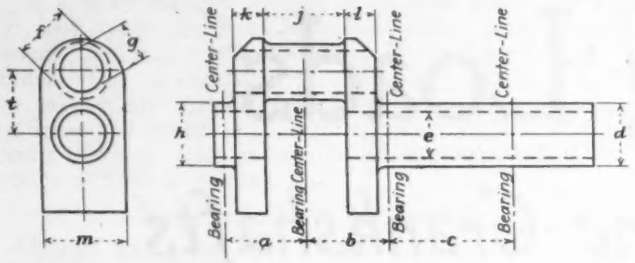


FIG. 2—CRANKPIN-BEARING LOAD DETERMINED FROM GAS FORCE AND INERTIA FORCE

Among the Things That Can Be Found with a Diagram like This Are the Sum of the Main-Bearing Loads at Any Crank-Angle, Represented by the Gas-Force Vector; the Crankpin-Bearing Load at Any Speed and Crank-Angle; the Variation in Angle of the Crankpin-Bearing Load, for Guidance in Locating the Oil-Hole; and the Tangential and Radial Components of the Crankpin-Bearing Load

TABLE 1—PRINCIPAL DIMENSIONS OF CRANKSHAFTS TESTED, IN.



Dimension	Crankshaft A	B	C	D	E	F
a	3 5/16	4 1/8	3 1/2	3 3/4	4 1/8	4 1/4
b	3 5/16	4 1/8	3 1/2	3 3/4	4 1/8	4 1/4
c	6	5	5 1/2	5 3/4	7 3/4	5 3/4
d	2 9/16	3	2 7/8	2 7/8	3 1/4	3 7/8
e	1 3/8	1 15/16	1 5/8	1 5/8	1 3/4	3 1/8
f	2	2 1/4	2 1/2	2 1/2	2 3/4	3 1/4
g	1	1 7/16	8/4	3/4	1	2 9/16
h	2 3/4	3 1/4	3 1/8	3 1/8	3 1/8	3 9/16
j	3 3/4	3 3/4	3 7/8	3 3/4	4 1/4	3 15/16
k	1 5/16	1 7/16	1 3/16	1 5/16	1 3/8	1 11/16
l	1 5/16	1 1/8	1 1/4	1 3/8	1 1/4	1 5/16
m	2 5/8 / 3 3/8	3 1/2 / 3 1/8	3 3/4	3 3/4	3 7/8	front 4 3/4 / rear 4 1/8
t	2 3/4	2 3/4	2 7/16	2 7/8	3 3/16	3 7/16

of the moving parts can be added later. Taking the indicator card as a basis, the first step is to sum vectorially the forces due to gas pressure acting along the connecting-rods. This process is shown in Fig. 1. It will be noted that, at the 10-deg. crank-angle, cylinders numbered 2, 4, 5, 7 and 9 have such small gas pressures that it is unnecessary to consider them in making the diagram.

Making a Diagram of Forces

In a radial engine, the forces on the crankshaft are repeated $n/2$ times during one revolution, n being the number of cylinders. Thus it is necessary to consider only one cycle or 80 deg. of crank travel in a nine-cylinder engine. After making a series of diagrams similiar to the one at the right in Fig. 1 for various crank-angles, it is possible to construct Fig. 2. In this figure the gas forces acting on the crankshaft have been laid off from a single point and at their various angles to the center-line of the crank cheek. Since the assumption is that the inertia loads are balanced by the counter-weights, the resultant inertia-load will lie along the center-line of the crank cheek, and its value will vary with the square of the speed of rotation. A point may be marked on the center-line of the crank cheek to represent the end of this vector for any given speed. We may, therefore, divide this line into distances representing forces at various engine-speeds. The resultant load on the crankpin is the vectorial sum of the inertia force and the gas load at the particular crank-angle and speed at which the value of the resultant crankpin-bearing load is desired. Since the inertia forces are assumed to be completely balanced by the counterweights, the sum of the main-bearing loads at any angle is represented by the gas-load vector at that particular angle. For figuring crankshaft stresses, it is desirable to divide these loads into their tangential and radial components.

If the crankshaft had only two bearings equally spaced from the central plane of the cylinders, it would be necessary only to assign one-half of the value of this gas-load force to each of the bearings. A complication is introduced by the fact that nearly all radial-engine crankshafts are supported in three bearings. The front bearing, which is intended to take the thrust load from the propeller, actually takes considerable radial load. When all three bearings are considered, the problem becomes one of a statically indeterminate beam which must be solved either experimentally, by the method of least work, or by the theorem of three moments. Since all crankshafts are very irregular in shape, it is not possible to get accurate values of the stiffness of a shaft without resorting to a practical test. Such tests were made at the Massachusetts Institute of Technology on six representative radial-engine crankshafts.

Tests Made for Deflection

The method of testing these shafts was to apply a concentrated load to the center of the crankpin, supporting the shaft in the two main bearings only. The reactions at the main bearings were measured by means of ring gages. The deflection of each shaft was measured by means of a bar passing through the shaft supported under the thrust bearing and the front main-bearing, with a dial indicator contacting with the shaft under the rear bearing. A photograph of the set-up is reproduced in Fig. 3. The shafts that were tested are shown in Fig. 4, and their principal dimensions are given in Table 1. After recording the bearing load and deflection, sufficient radial load was applied at the thrust bearing to bring the three bearings into line, which condition was shown by the indicator. The main-bearing

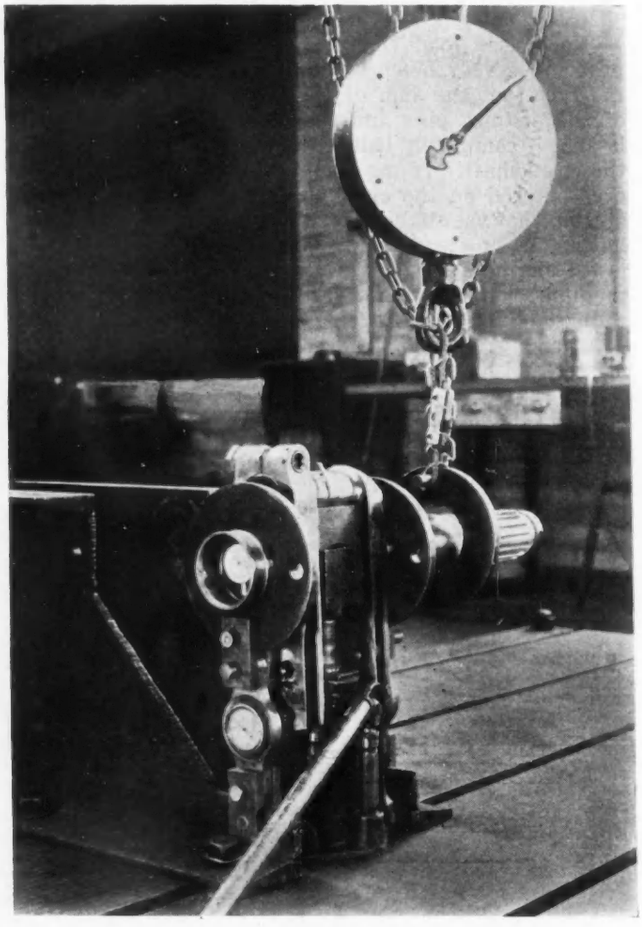


FIG. 3—DEFLECTION TEST OF RADIAL-ENGINE CRANKSHAFT

The Hydraulic Jack for Applying the Load Is Seen underneath the Crankpin; the Deflection Gage Is Inside the Bearing at the Left, and the Ring Gage Is Underneath

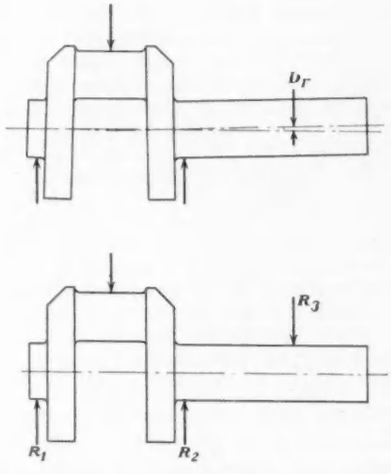
reactions were again recorded. With these data it was possible to calculate the reaction at the third bearing.

Three separate conditions of loading were tried. In the first case, a load was applied to the crankpin in a radial direction. In the second case, the crankpin load was applied in a tangential direction. It was thought that under this condition of loading the shaft might deflect in a direction perpendicular to the applied load as well as in the plane of the applied load, on account of the lack of symmetry of the arrangement. This deflection was found to be very small, on the order of 0.001 in., for the maximum gas load, so it was neglected. The third condition of loading was intended to simulate the effect of inertia forces. A load was applied to the crankpin in a radial direction and two loads were applied to the crank cheeks, at the counterweight points, the sum of which was equal and opposite to the load applied to the crankpin. Deflections were measured as before and the shaft was straightened by applying loads to the two main-bearings and the thrust bearing. In this case the load applied to the rear main-bearing was measured directly and the other loads calculated from it.

Loads and Deflections Tabulated

Diagrams at the tops of Tables 2, 3 and 4 show the three methods of loading. That at the top of Table 3 shows the direction of the actual loads in the engine. The direction of the applied loads was reversed, as is indicated in Fig. 3, for convenience. This makes no appreciable difference in the results, since the deflections were small. Assuming the two main-bearings to be fixed, the deflection of the shaft at the thrust bearing was calculated. The results of these tests have been summarized in Tables 2, 3, 4 and 5. The bearing reactions are given in Tables 2, 3 and 4 both in pounds and

TABLE 2—BEARING REACTIONS AND DEFLECTIONS FOR MAXIMUM RADIAL GAS-LOAD ON CRANKPIN AT RATED POWER



Crankshaft	Crankpin Load, Lb.	R_1 Lb.	R_1 Percentage	R_2 Lb.	R_2 Percentage	R_3 Lb.	R_3 Percentage	D_r, In.
A	8,440	3,380	40	6,000	71	930	11	0.0133
B	10,400	3,740	36	9,100	87.5	2,440	23.5	0.0153
C	11,200	4,260	38	8,680	77.5	1,740	15.5	0.0073
D	13,800	5,240	38	10,800	78	2,200	16	0.0086
E	15,650	6,260	40	11,100	71	1,720	11	0.0136
F	15,000	5,920	39.5	11,600	77	2,480	16.5	0.0123
Average			38.6		77.0		15.6	0.0117
Variation, percentage of mean value		+3.6 −6.7			+13.6 −7.8		+51.0 −29.0	+31.0 −38.0

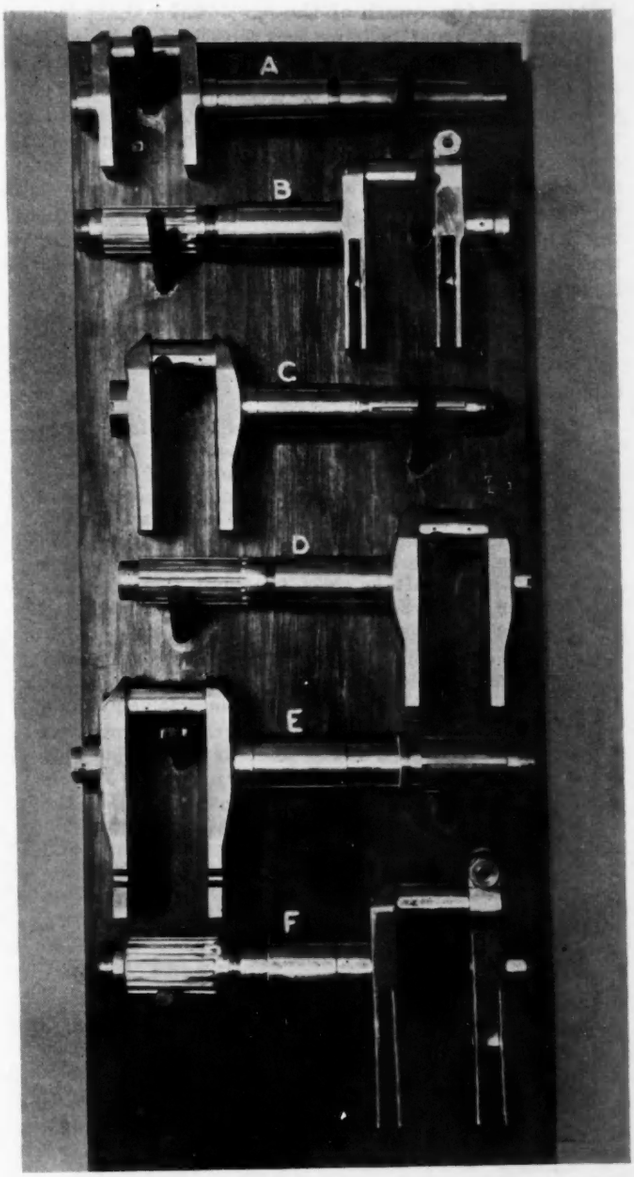


FIG. 4—CRANKSHAFTS THAT WERE SUBJECTED TO TESTS

in percentages of the corresponding crankpin loads and in Table 5 in percentages of the radial gas-load.

All loadings on these shafts were concentrated at the centers of the bearings. This is a somewhat more severe condition of loading than the actual case, and undoubtedly does to some extent increase the transference of load from the rear bearing to the front, but tests made to determine the magnitude of the error introduced showed it to be so small as to be negligible. Shaft *B* was tested with two equal concentrated loads on the crankpin spaced at the quarter points. The deflection was less than 3 per cent lower than that obtained when using a single concentrated load at the center of the crankpin. Other factors which tend to reduce the transference of load are the flexibility of the crankcase and the clearance in the bearings. In my opinion, the bearing supports of a radial engine deflect very little under load. The effect of the clearance in the bearing is probably also rather small and is inter-

related with the length of the part of the shaft located between the thrust bearing and the front main-bearing.

It will be noted that all the factors listed in the foregoing paragraph tend to reduce the transference of load. Consequently the tables in this report represent an extreme case. The other extreme is reached by neglecting entirely the radial load on the thrust bearing, as is usual practice. I believe that the results of these tests indicate much more nearly the true value of the bearing loads in the engine under actual operating-conditions than do tests in which the radial load on the thrust bearing is neglected.

Front Main Bearing Is Heavily Loaded

The following generalizations may be made from the tabulated results:

(1) There is a transference of load to the front main bearing due to the radial reaction on the thrust bearing. This transference is of sufficient magnitude to be of considerable importance in the design of the crankshaft and its bearings. The amount of the transference depends on the relative length and stiffness of the section of the shaft between the main bearings and the section between the front main-bearing and the thrust bearing.

(2) The effect of the inertia forces on the main-bearing loads, which effect is due only to the deflection of the shaft, is comparatively small.

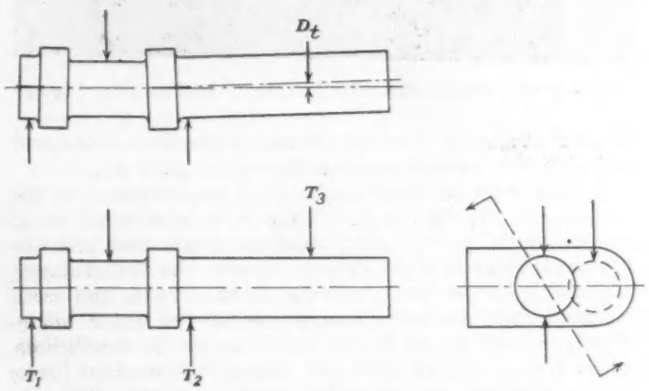
(3) The transference of load when the crankpin load is applied in a radial direction is considerably less than when the load is tangential. This is to be expected on account of the fact that the tangential loads cause torsion in the crankpin and crank cheeks in addition to bending, and consequently the section of the crankshaft between the main bearings is considerably less stiff in the tangential than in the radial direction, while the shaft between the front main-bearing and the thrust bearing has the same stiffness in either direction.

(4) There seems to be a remarkably close agreement in all shafts tested in the distribution of the main-bearing loads, and it seems that, for calculation of conventional radial-engine shafts, it is sufficiently accurate to use the average values of these loads.

(5) The thrust-bearing load however shows considerable variation. Either measuring the stiffness of the shaft or making some kind of assumption based on a comparison of the shaft with one whose stiffness has already been measured is necessary to get any accurate idea of this load.

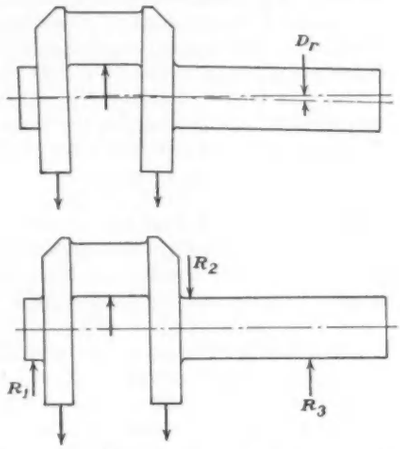
(6) The deflection, as would be expected, is very different for the various shafts. A consideration of individual shafts seems to show that shafts *C*, *D* and *E* are relatively less stiff in a tangential direction than shafts *A*, *B* and *F*. This may be explained by the fact that shafts *C*, *D* and *E* are two-piece shafts having splined joints. This construction makes the equivalent length of the crankpin in torsion somewhat longer than its measured length and consequently reduces the stiffness of the shaft under a tangential loading. Shaft *A* is a solid shaft. Shafts *B* and *F* are two-piece shafts with the crankpin clamped in the rear cheek. The use of plain journal-bearings on shaft *B*, so that the center of support for the shaft is not as

TABLE 3—BEARING REACTIONS AND DEFLECTIONS FOR MAXIMUM TANGENTIAL GAS-LOAD ON CRANKPIN AT RATED POWER



Crankshaft	Crankpin Load, Lb.	T_1 Lb.	T_1 Percentage	T_2 Lb.	T_2 Percentage	T_3 Lb.	T_3 Percentage	D_t, In.
A	4,140	1,350	31.5	3,680	89	850	20.5	0.0081
B	5,100	1,480	29	5,400	106	1,780	35	0.0043
C	5,500	1,490	27	5,650	102.5	1,620	29.5	0.0064
D	6,760	1,820	27	6,970	103	2,030	30	0.0091
E	7,670	1,960	25.5	7,720	100.5	1,990	26	0.0102
F	7,350	2,350	32	6,980	95	1,980	27	0.0066
Average			28.7		99.3		28.0	0.0082
Variation, percentage of mean value		+11.5 −11.0			+6.7 −10.2		+25 −27	+24 −20

TABLE 4—REARING REACTIONS AND DEFLECTIONS FOR INERTIA LOAD AT RATED SPEED



Crankshaft	Crankpin Load, Lb.	R_1 Lb.	R_1 Percentage	R_2 Lb.	R_2 Percentage	R_3 Lb.	R_3 Percentage	D_r, In.
A	−8,250	100	1.2	−210	2.5	−110	1.3	0.0014
B	10,100	360	3.6	950	9.4	590	5.8	0.0033
C	−9,960	170	1.7	−280	3.8	−210	2.1	0.0007
D	−14,200	310	2.1	−710	4.9	−400	2.8	0.0016
E	−20,150	340	1.7	−680	3.4	−340	1.7	0.0017
F	−19,700	240	1.2	−580	2.9	−340	1.7	0.0014
Average			1.9		4.8		2.6	0.0017

TABLE 5—BEARING REACTIONS AND DEFLECTIONS FOR MAXIMUM RADIAL GAS-LOAD ON CRANKPIN AT RATED POWER COMBINED WITH INERTIA LOAD AT RATED SPEED

Crankshaft	R_1 [a]	R_2 [a]	R_3 [a]	D_r, In.
A	41.2	68.6	9.7	11.9
B	39.4	78.4	17.8	12.0
C	39.4	74.1	13.6	6.4
D	40.2	73.1	13.1	7.0
E	42.2	66.6	8.8	11.9
F	41.0	73.5	14.3	10.9
Average	40.6	72.6	12.9	10.0
Variation, percentage of mean value	+3.4 −3.0	+8.0 −8.3	+38 −32	+20 −36

[a] Bearing reactions are given in percentage of radial gas-load as found in Table 2.

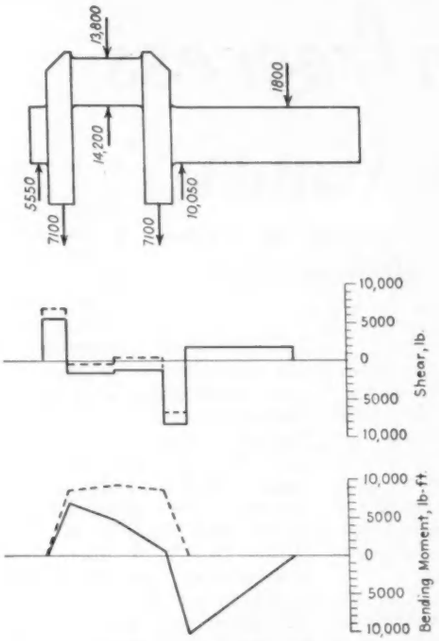


FIG. 5—SHEAR AND BENDING MOMENTS OF CRANKSHAFT *D* WITH RADIAL LOAD

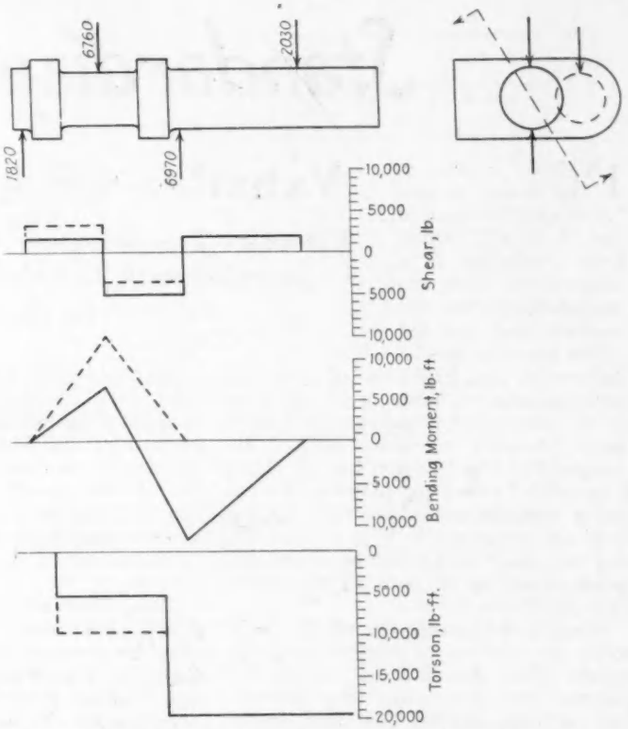


FIG. 6—SHEAR AND BENDING AND TORSIONAL MOMENTS OF CRANKSHAFT *D* WITH TORSION LOAD

close to the crank cheek as in the other shafts, explains to some extent why shaft *B* shows relatively large deflections.

As will be seen from the tables, the front main-bearing of each shaft carried approximately twice the load of the rear main-bearing. The front bearing should therefore be considerably larger than the rear bearing to make a design consistent. On only two shafts was this found to be the case. The other shafts either had main bearings of the same size or the rear bearing was larger than the front. It might also be possible, in view of the lighter loading, to make the rear half of the crankcase somewhat thinner than the front half.

The shear and bending-moment diagrams for shaft *D*, based on the measured bearing-loads, are shown in Figs. 5 and 6. For comparison, the shear and moment diagrams derived by assuming no radial load on the thrust bearing are superimposed in dotted lines.

It will be noted that the bending and twisting moments in the crankpin section, derived from the actual loads on the shaft, are considerably smaller than those found if the radial load at the thrust bearing is neglected. The twisting moments in the crank cheeks, which are shown on the bending-moment diagram, are approximately the same for the front and rear cheeks, but are in opposite directions. The bending moment in the front cheek caused by the radial load is considerably less than the corresponding load in the rear cheek.

There is no apparent objection to placing the clamp of split crankshafts on the front cheek instead of the rear cheek. This location has several advantages: it moves the weight of the joint toward the front end of the crankshaft, thereby tending to reduce the primary torsional-period; it makes possible shortening the rear end of the engine by the difference in width of the cheeks; and the crankpin can be machined in a smaller lathe.

Meetings of the Society

(*Concluded from p.* 406)

been formulated, the technical sessions will be held in the mornings and evenings, none being scheduled for the afternoons, which will thus be left open for sports. To schedule the necessary committee meetings without conflicting, on the one hand, with the technical sessions and, on the other hand, with the recreational events, presents a real problem, which the Meetings Committee is endeavoring to solve by holding as many of the committee meetings as possible on Sunday, before the other features of the program get well under way. Such committee meetings as cannot be fitted into the time available on Sunday will be run on succeeding days of the week as dinner-meetings, beginning at 5:30 o'clock, with the idea of adjourning in sufficient time to enable committee members to attend the evening session.

The Meetings Committee and the other committees sponsoring the technical programs announce their intention of beginning each session on time and ending it on time. Adherence to this plan will unquestionably contribute in no small measure to the success of the Summer Meeting.

Standardization Progress

Valuable Oil Charts Available

Viscosity-Temperature Chart Prepared in Conjunction with Lubricant Viscosities Adopted by the Society

IN THE course of the study by the Lubricants Division of the Society's Standards Committee of a method for designating lubricating-oil viscosities, that had led to the adoption by the Society of the crankcase-oil viscosity numbers and, in January of this year, of the transmission and rear-axle lubricants viscosity numbers, one of the members of the Division has developed a simplified chart for plotting the viscosity temperature curves. The section area of the chart is 13¼ x 18¼ in., and the chart is printed on onion-skin paper made up in pads of 25 sheets, 16⅝ x 19¾ in.

When investigating the effect of viscosity in relation to engine cranking-speeds and gearshifting, it is important to determine the viscosities of the engine oils and transmission lubricants at low temperatures, hence this chart was developed to permit of straight-line plotting of viscosities of from 200,000,000 Saybolt universal sec. at 25 deg. fahr. below zero to 36-sec. viscosity at 450 deg. fahr. The chart has been checked to 50,000,000-sec. viscosity, and it is possible to carry curves on the heavier-viscosity lubricants used for rear axles and transmissions as well as for extremely low and high-temperature information that is not available on other charts. In addition, plotting the straight-line viscosity curve of the engine oil by first fixing the viscosity determinations at 100 deg. and 210 deg. fahr., enables one to ascertain the correct viscosity readings at any desired temperature. By fixing the 50,000-sec. viscosity mark as the maximum for easy starting at low temperatures and the 60-sec. viscosity mark as the minimum for warm-weather or high-speed safe performance, it is possible to determine the temperature range over which such an oil will prove serviceable.

As this chart was prepared in connection with the present S.A.E. Recommended Practices (pp. 605 to 607, 1931 edition of the S.A.E. HANDBOOK) for lubricant viscosity numbers, it is felt that it will be of much value to automotive engineers in their study of engine, transmission and rear-axle lubricants as well as to the oil company engineers.

This information is published in the S.A.E. JOURNAL so that the charts may be secured by those who desire them by communicating directly with the Sinclair Refining Co., 45 Nassau Street, New York City, attention of C. M. Larson, supervising engineer. The price per 100 sheets is $4, which should be remitted with orders.

Plain Limit-Gage Standard To Be Revised

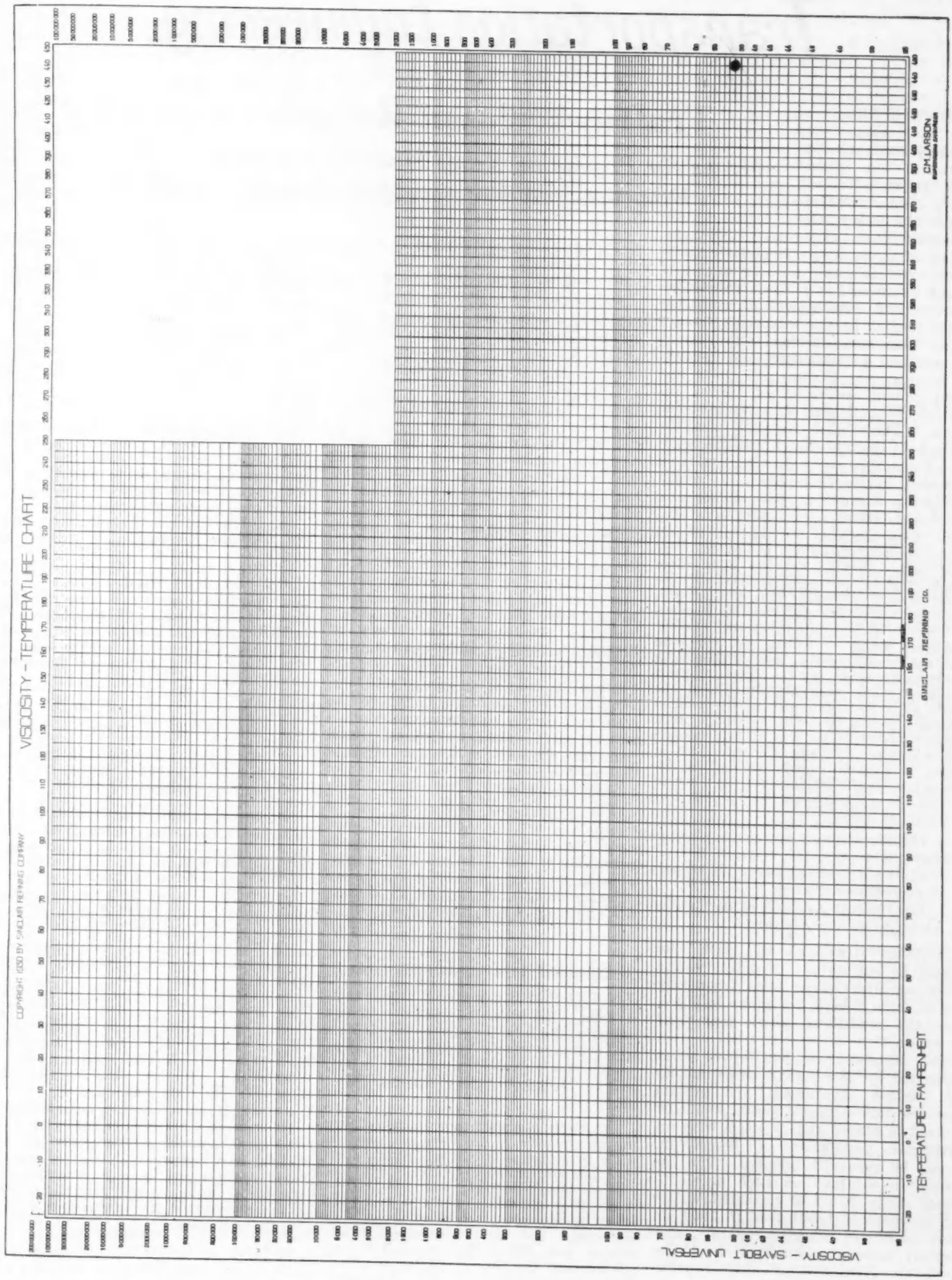
ONE of the earlier projects taken up under the American Standards Association, successor to the American Engineering Standards Committee, was the standardization of Tolerances, Allowances and Gages for Metal Fits, which was approved by the A.S.A. and published in 1925. The report was received by the industries with varying degrees of interest but apparently was not generally adopted by them. Consequently it was decided to review the subject, especially from the point of view of the present industrial requirements in the selection of allowances and tolerances for general work. The Sectional Committee has therefore been reorganized to review the work of the previous Committee, study present industrial practices and recommend such revisions as may be desirable in the present tentative American Standard.

This Committee is organized and working under the procedure of the American Standards Association as the Sectional Committee on Standardization of Plain Limit Gages for General Engineering Work. The representatives of the Society on it are H. E. Brunner, SKF Industries; G. L. LeBar, Spicer Mfg. Corp.; D. W. Ovaitt, Buick Motor Co.; T. F. Rogan, Continental Motors Corp.; and F. W. Stein, Fairbanks, Morse & Co. Inquiries for information regarding this project should be directed to the representatives of the Society or to the Society's office in New York City.

Aircraft Division To Discuss Standards on April 20

FURTHER progress in the development of aircraft standards has been made by the Aircraft Division of the Society's Standards Committee since the Annual Meeting of the Society last January, and a meeting of the members of the Division will be held in Detroit probably on April 20 after the close of the 19th National Aeronautic Meeting of the Society there on April 16.

Among the subjects that will be discussed are airplane brakes, tires, rims and wheels, indicating instruments, structural materials and other subjects for which Subdivisions were appointed. Chairman J. F. Hardecker anticipates that a number of definite reports should be made ready for final consideration and adoption by the Society at the Standards Committee Meeting at White Sulphur Springs on Wednesday, June 17.


VISCOSITY - TEMPERATURE CHART
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Transportation Engineering

Traffic-Accident Records

Means for Promoting Better Statistics and More Extensive Studies of Accident Causes

COMMITTEES of the First and Second National Conferences on Street and Highway Safety and those Conferences themselves emphasized the importance of more adequate statistics and more extensive studies of the causes of accidents as a basis for accident reduction and development of more orderly traffic. In the intervening years there has been decided improvement in accident investigation and records in some of the States, and there has been general improvement in the recording of accidents on a Nation-wide basis. The Third National Conference, held in 1930, which had the benefit of another special study of this question by its Committee on Traffic Accident Statistics, summarizes its recommendations as follows:

In accordance with the Uniform Vehicle Code, statutes should be passed in every State where they do not now exist which would make it the specific business of some State agency, preferably that clothed with authority for issuing and revoking licenses, to receive traffic-accident reports, whether occurring within or without the corporate limits of municipalities, and it should be made obligatory by law for those concerned to report traffic accidents, for use of the traffic authorities only, with provision of an adequate penalty for failure to report. Reasonable uniformity in reporting and tabulating schedules, with standard definitions of terms, is essential. Sufficient detailed information should be included to indicate clearly the circumstances surrounding the accident, as follows:

(1) Recklessness, carelessness or incapacity of persons

(2) Fault of mechanism of the vehicle, or maintenance of same

(3) Physical condition of the locality where the accident occurred

Accident spot-maps and card files should be maintained to detect points where accidents occur most frequently and to form a basis for plans to eliminate the conditions which may lead to accidents.

The standard accident-report form developed by cooperative effort among the various government and private agencies during recent years, and now utilized in States and/or cities with an aggregate population of 68,000,000, should be generally adopted. The information obtained on such accident-report cards should be classified, utilizing mechanical tabulation if 1000 or more cases are reported monthly, and monthly accident-summaries should be prepared. The uses of such reports may be classified as:

(1) Educational and legislative
(2) Engineering
(3) Judicial

Prevention of traffic accidents is a problem of education, engineering and enforcement, and accident records should play an important part in each of these three fields of work.

Comprehensive research into the causes of street and highway accidents is needed for the purpose of determining the direct and contributing causes of accidents and the frequency of the various hazards, and of pointing the way to improvements from the standpoint of safety in design, construction and adjustment of motor-vehicles; design, construction and maintenance of streets and highways; traffic laws, regulations, signs, signals, markings and other devices for the control of traffic; and methods of examining applicants for operators' licenses, including special examinations for chauffeurs, persons suffering from physical or mental handicaps and persons who may be brought before the courts or motor-vehicle commissioners for repeated traffic violations. Such research should obviously embrace thorough study of the efficacy of intended remedies.

The great and increasing toll of death and injury and the economic loss from traffic accidents, rapidly approaching a billion dollars a year, emphasize the importance of adequate accident records and analyses as a basis for applying remedial measures.

Special Driver-Inspection

IN TRAINING drivers of buses, taxicabs, and other passenger-carrying vehicles, the following items in addition to ordinary safe-driving practices should receive special attention, according to National Safety Council Pamphlet D-3.

(1) Safety is always more important than the maintenance of schedules. It must be made clear that no driver can expect to excuse himself for an accident by claiming pressure from schedules.

(2) It is the driver's duty to guard the safety of passengers. He must be made to understand that he is virtually a public servant and carries the responsibility of safeguarding the lives of people who have intrusted themselves to his care. This means that he must protect his vehicle from the careless actions of drivers of other vehicles on the highway. Therefore he must take precautions that drivers of private cars often consider quite unnecessary.

(3) As a safety measure, all drivers of passenger-carrying vehicles should be instructed to permit boarding and alighting only when the vehicle is at rest, and to have all doors closed when the vehicle is in motion.

(4) Special instruction should be given in how to handle intoxicated or unruly passengers, who may injure either themselves or other passengers or who may so distract the operator as to interfere with safe driving.

(5) Stopping in proper cab stands or loading points is a sound safety practice; parking or even stopping in a double line to load or unload passengers is a practice which often leads to accidents. It is best to come to the curb at the proper place.

(6) Drivers can prevent accidents by warning passengers not to run in front of the vehicle after alighting.

(7) Careful inspection of the vehicle by the driver before he takes it out is important. He should examine not only the condition of brakes, horn and other equipment involved in actual driving, but also seats, hang straps and windows, for defects which might cause injury to passengers. It is often found helpful to require each driver to check daily a printed list of items as he inspects his vehicle. Such a list should be turned in before the driver leaves the garage.

(8) The habit of making change and issuing transfers only when the vehicle is at rest should be cultivated.

In driving light delivery-trucks and salesmen's cars, instruction in the following items will assist in avoiding accidents:

(1) Keep the mind on driving while on the road. Avoid thinking about the call just made or the one about to be made.

(2) Do not attempt to look up addresses or watch for house numbers while the vehicle is in motion.

(3) Complete records and sort packages only when the car is standing. Do not attempt to do so while driving. After having stopped to arrange the records or load, make sure the way is clear before starting; do not assume that conditions have remained as they were when last observed.

(4) Never block alleys or private driveways.

(5) Avoid double-parking, even for extremely short deliveries.

(6) Make a practice of leaving the car, even for an instant, in such a condition that it cannot start of its own accord or be started by children.

Drivers of heavy trucks should receive instruction in these subjects in

addition to cautions for ordinary driving:

(1) Backing, under all conditions, and especially up to platforms or curbs
(2) Secure loading and the avoidance of overloading
(3) The marking of loading limits by flags or lights
(4) The use of a helper in watching for danger, especially in backing
(5) Proper connection and control of trailers
(6) Safe speeds under various conditions of road and load
(7) Watching for weak manhole covers, insecure temporary roadways, and bridges posted for load limits
(8) Hogging the road
(9) Forbidding unauthorized passengers to ride.

Special Taxation for Motor-Vehicles

Sound and Equitable Principles for Its Control Set Forth by the Motor-Vehicle Conference Committee

THE STATE should be the sole special taxing agency. Federal, County and Municipal Governments should be excluded from the field.

The motor-vehicle tax should be simple in form and distributed in equitable and just proportion between the different types of motor-vehicles.

No highway should be improved by expenditure of public funds in excess of its earning capacity. The return to the public in the form of economic transportation is the sole measure of justification for the degree of improvement.

All money raised by such special taxes should be placed in the State Motor-Vehicle Highway-Fund and, to secure the best results, should be expended under the supervision of the State Highway Department.

The cost of building and maintaining adequate systems of highways should be distributed in an equitable relation to the benefits derived. These may be summarized as benefits to:

(1) Society in general; such as influence on education, recreation, health, fire prevention, police protection, the National defense, the postal service, living and distribution costs
(2) Definite groups; such as agriculture, manufacture, labor, railroads, mining, forestry and waterways
(3) Property served
(4) The road user

For the purpose of apportioning costs in relation to benefits received, all highways can be divided into two classes: First, those used by the general motoring public; second, those which perform a purely local service-function.

Special motor-vehicle taxes should be levied and used only for the improvement and maintenance of highways used by the general public; that is, for general highway-traffic flow-lines.

The wide variance in valuations, tax burdens, number of motor-vehicles in use and the status of highway development in the several States prevent the adoption of any fixed formula as to the proportion of the total costs of highways of general use which should be paid for from motor-vehicle funds. Generally speaking, however, the following principles may be set forth.

(1) In States where the income from motor-vehicles is insufficient to meet all of the maintenance costs of highways for general motor-vehicle use without undue burden to the individual motorist, such funds should be applied first to the maintenance of inter-State and State-highway systems.

(2) In States where the income from motor-vehicles is sufficient to meet all maintenance costs of highways for general motor-vehicle use without undue burden to the individual motorist, any surplus should be used for this class of highway reconstruction and administration costs.

(3) In States where the number of motor-vehicles will bring in large sums in excess of maintenance without placing undue burdens upon the individual motorist, such surplus should be used to defray all the costs of maintenance and a substantial share of all of the other costs of highways for general motor-vehicle use.

(4) In those States where the motor-vehicle income is more than sufficient to meet maintenance costs of highways for general motor-vehicle use without undue burden to the individual motorist, it may be found advisable to use such surplus for the purpose of defraying all or part of the costs of bond issues to expedite construction of economically desirable motor-vehicle highways.

Roads of a purely local interest, serving only local needs, should be financed out of local revenues obtained from local general taxes. Special assessments on adjoining land to defray a portion of the costs of such roads may be justified.

Where extraordinary improvements are undertaken in the vicinity of or serving congested areas of population the increment, if any, in property valuation following the improvement, should be drawn upon to defray an equitable portion of the cost.

Irrespective of the particular form of special tax of the motor-vehicle, whether registration fees or motor-fuel taxes, the aggregate amount of these taxes in any one year should not be so great as to impose an undue burden on the individual motorist.

Traffic Officer and Driver Cooperation

AT THE SCHOOL of instruction for drivers maintained by the Hoffman Beverage Co., Newark, N. J., straightforward brief lectures are given by the supervisor and others in which some of the finer points of the successful safe driving of motor-vehicles are brought out.

As stated by G. A. Rogers, a representative of the company, in a paper he presented recently at the commercial-vehicle session of the Second Annual Greater New York Safety Conference, a National Safety Council event, courtesy is a paramount factor of the company's policy. The manner in which the various phases of the subject are treated is indicated in the following "talk" cited by Mr. Rogers:

Straight Talk to Drivers

The traffic-officer's job is a mighty important job and a very necessary one. You may be surprised to hear it, but a traffic officer will go out of his way to befriend you and help you if you will only let him do it. If you have committed some violation of the traffic law and a traffic officer quite properly takes you to task for it, bring your courtesy to the front, admit your error and realize the possibilities of an accident which your disobedience of the law might have caused. Just try standing out there in the street for eight hours and guiding thousands and thousands of vehicles which are driven by all sorts of drivers. I do not believe that there is a driver in this room who would swap jobs with a traffic officer.

Suppose that a traffic officer makes you stop short. Why not be thankful that he saw some danger that you did not see? Possibly you did not see some child dart across the street. You may not have seen or heard that ambulance which was coming up a side street. The traffic officer may see many dangers that you cannot see; therefore remember that he is there to do a necessary job. Develop your courtesy to such a degree that you and the traffic officer work together and pull together as a team that is trying to reach the goal of Public Safety.

Never drive through the scene of an accident. Information regarding accidents becomes distorted by the people who witness them. If your truck is conspicuous because of size and other characteristics such as lettering, color and the like, someone may notice it and in some way or other connect it with the accident even though you and your truck are in no way involved. This is especially true after an accident in which some person has been injured or killed and the bystanders do not know just how the accident happened. If you and your truck become involved in this way, you may have difficulty in proving that you had no connection with the accident.

Mr. Rogers remarked further that the city's police department has cooperated splendidly in this educational endeavor, and has from time to time sent instructors from its traffic department to give the company assistance in training its drivers.

News of Section Meetings

(*Continued from page* 415)

Mr. Kreusser's comparison of the airplane with the automobile.

A. E. Larsen, expert on the Autogiro, then read a paper on this type of flying-machine and showed motion pictures demonstrating early performances of British and American Autogiros and also pictures of recent experimental flights. He pointed out that, contrary to what the name implies, the rotating wings have no gyroscopic action. He described how the wings shift position automatically, thus compensating for the difference in air-flow between the oncoming blade and the receding blade. The students plied Mr. Larsen with many questions indicating a tremendous interest in the machine.

Mr. Taub announced that the next student-junior meeting will be held on March 31 and promised an interesting paper on Mathematics as an Engineering Tool, by R. N. Janeway, in addition to talks by other noted speakers.

Oregon Section's Busy Day

Breakfast, Luncheon and Evening Meetings Held—Installment Buying and Efficient Thinking Discussed

MORE than 60 members of the Oregon Section and their guests from the Progressive Business Men's Club and the Executives Club, of Portland, attended the banquet meeting held in the Crystal Room of the Benson Hotel on Thursday, March 12. The Section was fortunate in having as one of its guests John A. C. Warner, General Manager of the Society.

West Leads in Transportation Ideas

Of particular interest to those present were Mr. Warner's remarks concerning automotive transportation development in the West. He pointed out that transportation companies in the East are looking to the western operators for the newer, more progressive ideas pertaining to the work. Favorable climatic conditions, together with the long distances of the haulage, have been factors contributing to a remarkable development in three types of transportation, that is, motorcoach, freight truck and aviation. Many ideas have been developed in the West, and operating plans have been worked out that have been advantageously copied by eastern operators.

"This is particularly noticeable in aeronautics, as I was impressively reminded of while going through one of the finest airplane factories I have seen anywhere," said Mr. Warner, referring to the Boeing factory.

Basic Factors in Extending Credit

"Deferred payments have come to be a major factor in selling, said G. McGuire Pierce, in discussing the topic, Automobile Financing. "Installment buying is no longer confined to a few articles that sell for a considerable amount, but now covers almost the entire field of merchandising. Investigation has shown that the system has been applied to everything from mechanical refrigerators to silk hose. Approximately 70 per cent of all automobile sales are now financed in this way. So important has this method of selling become that much studying has been done to determine the important factors to be observed as a basis of credit accommodation. It is generally agreed that three very important factors are to be considered: First, this method of financing should be applied only to necessity articles, and the price should be well represented by value; second, the length of the deferred obligation should be as short as possible within the ability of the purchaser to pay and should not be more than from one-fourth to one-half the period of use expectancy; and third, the character of the purchaser must be favorable."

HARLEY W. DRAKE
Chairman of Oregon Section

Engineering Methods in Thinking

The third speaker on the program was Frank H. Skipper, personnel director of the Pennzoil Co., who for more than an hour held the close attention of his audience to an interesting and instructive address on the application of engineering logic and efficiency to the process of thinking. Education has too long been a process of memorizing facts and not a system of mental exercises for developing thinking capacity, according to Mr. Skipper. If some of the efficiency studies that have been applied to factory processes could be applied to thinking, some surprising conditions would be found. Very few mentalities have been trained to utilize more than a very small percentage of their thinking ability. Better-trained individual capacity for thinking and more cooperative thought would soon accomplish amazing results.

The Oregon Section spent one of its most interesting and busy days with Mr. Warner, who arrived from Seattle early in the morning and was met at breakfast in the Multnomah Hotel by 14 members to become acquainted and discuss Section activities. At noon, Chairman Drake, Mr. Skipper, Mr. Warner and many members of the Section met with the Progressive Business Men's Club for luncheon, where the Section had charge of a part of the program. From 130 to 150 persons were in attendance, and the affair was very successful. Mr. Warner spoke very briefly, and Mr. Skipper gave a short talk on Depressions and Their Causes and Cures.

At the April meeting of the Section C. H. Stokke is to give a paper on Cylinder Reconditioning, and Fred H. Carruthers will present a paper on Correct Steering.

First Kansas City Section Meeting

TWELVE members and 45 guests attended the first technical meeting of the Kansas City Probationary Section on Feb. 16 at the Auto Tavern, after a chicken dinner. Section Chairman R. H. Van Ness announced the selection of W. B. Wightman, S. S. Sherriff, I. B. Morgan, G. C. Boyer and W. O. Charles for the Nominating Committee, and the appointment of the following Committee Chairmen: Ray B. Mason (Reception), R. J. Collins (Membership) and N. A. Wilson (Highway).

W. S. James, research engineer of the Studebaker Corp. of America, pre-

sented a paper on Free-Wheeling which was substantially identical with the one published in the January issue of the S.A.E. JOURNAL beginning on p. 31. Great interest in the subject was shown by members and guests, many of whom asked the speaker about various phases of free-wheeling and related matters.

New Canadian Duty Explained

Russell Tells Canadian Section Expected Effect on Automotive Industry—Demands Made on Batteries

FOR the first time since 1926 it is now more profitable for automobiles to be manufactured in Canada than to be imported from the United States, declared T. A. Russell, president of Willys-Overland of Canada and president of the Massey-Harris Co., at the meeting of the Canadian Section at the Royal York Hotel, Toronto, on Wednesday, March 18. He was speaking, by request, on the recent Order-in-Council of the Canadian Government standardizing the home market price of cars to a 20-per cent discount from the United States list prices plus duty thereon, and his remarks, coming from one so eminent in financial and automotive circles, were listened to with the keenest interest.

Canadian Plants Verged on Closing

Mr. Russell declared that, had the order not been passed, with present conditions continuing, automobile factories in Canada would have been forced to close their doors within the next three or four years.

When the tariff was reduced in 1926 from 35 per cent upon all cars to 20 per cent on the lower-priced cars and 27½ per cent on higher-priced cars, the growing popularity of the automobile resulted in no factories closing at that time. With the depression in industry last year, however, the burden began to press heavily. Mr. Russell said in part:

The heads of every concern, except perhaps Ford, felt that if conditions continued it would be better to close, and if no change had occurred that would have happened. The Canadian Government felt that, instead of raising the duty to 35 per cent, it might be an invitation to American manufacturers to establish plants in Canada if it standardized the home market to a 20 per cent discount from the United States list prices and required dealers to pay duty thereon. Now, instead of it being more profitable for United States manufacturers to supply from the United States, it is more profitable for them to supply automobiles manufactured in Canada, utilizing the raw materials that are available in Canada.

Most of us think that this will be in the interests of the Dominion. I feel that the confidence displayed by the Government in this understanding puts on us the onus of delivering value for every dollar we get from the Canadian public. I do not believe that the head of a single company in Canada likes the situation of his having to get 25 per cent more from the consumer than the United States consumer gives for the same automobile. It is not unnatural for the public to be dissatisfied and to ask for a change, for consumers feel that the spread must be excess profits that accrue to the builders. That is not the case, however, in Canada. Perhaps the margin of profit to the Canadian manufacturer of automobiles is no greater than to any other manufacturer; it may be less. The main difficulty he faces is the extent to which he is restricted by the specifications laid down by the manufacturers of the United States.

It is of the highest importance in this respect, asserted Mr. Russell, that standardization of parts for Canadian cars be realized, with the resulting lowering of cost. This will be the most pressing problem facing Canadian manufacturers in the next four or five years, and he urged the automotive engineers to cooperate and confer until they produce parts that can be utilized by all Canadian manufacturers in common. Until such an end is achieved they will be standing in their own light.

Lighton Talks about Batteries

L. E. Lighton, manager of automotive manufacturers sales for the Electric Storage Battery Co., of Philadelphia, was the second speaker of the evening and gave an illustrated talk on storage batteries, outlining chiefly the demands made on batteries by starting, lighting and ignition.

He discounted the popular idea that the starter makes a heavy drain on the battery and emphasized instead the need for correlating generator charging according to the use of a car or truck and its manner of operating. He warned sales agencies about expecting A1 performance from batteries that have been left without attention for long periods in the sales rooms and then delivered without inspection to the buyer. The reliance placed on the storage battery is indicated, he said, by the fact that on one 1931 car no provision is made for hand-starting.

There was a large attendance at the meeting, including several visitors from various parts of the United States, and R. H. Combs presided in the absence of Chairman McArthur.

Action Taken at March Council Meeting

A REGULAR meeting of the Council was held at the Pierre Hotel, New York City, on Tuesday, March 3, the following members of the Council being present: President Bendix, Past-President Warner, Vice-Presidents Glynn, Joachim, Lewis, Nutt, Marks and Parsons, Councilors Duesenberg, Shidle, Teetor and Tilston, Treasurer Spicer, David Beecroft and W. L. Batt of the Finance Committee, Secretary Warner, Assistant General Manager Veal and C. B. Whittelsey, Jr., assistant to the General Manager. The members of the Council were guests of President Bendix for luncheon.

As submitted, a financial statement of the Society as of Jan. 31, 1931, showed a net balance of assets over liabilities of $235,609.09, this being $11,028.62 less than the corresponding figure on the same date of 1930. The gross income of the Society for the first four months of the current fiscal year amounted to $115,061.15, and the operating expense was $121,059.27. The income for the month of January was $27,757.73, and the operating expense $34,973.21.

Reports were rendered on arrangements that have been made for the Aeronautic Meeting to be held in Detroit on April 15 and 16 and the Spring Production Meeting to be held at Milwaukee on May 6 and 7. The start of the Summer Meeting was changed to Sunday, June 14, instead of Monday, June 15.

Five applications for individual memberships were approved, together with two transfers in grade of membership. Forty-six additional applications, five transfers, six resignations, and four reapprovals, which had been acted upon by mail vote, were confirmed at the meeting.

The question of inviting other Societies to cooperate in Diesel-fuel research was discussed and the Council directed that the Society invite the American Society of Mechanical Engineers to join in the one committee to organize and properly coordinate a program for Diesel-engine fuel research work.

F. C. Mock was named to serve as a representative of the Society on the Division of Engineering and Industrial Research of the National Research Council for a term of three years.

E. F. Lowe and Robert W. Budd were named as members of the Transportation and Maintenance Activity Committee, and F. L. Faurote was named as a member of the Production Activity Committee.

Harold Lee Elfes

WORD has been received from the Motor Products Corp., of Detroit, of the death on Feb. 15 of Harold Lee Elfes, sales engineer for the corporation, following an attack of pneumonia.

Mr. Elfes had been a member of the Society since his election to Member grade in June, 1916, and was also a member of the Detroit Section. He was born at Castalia, S. D., in 1889, and from 1911 to 1913 was engaged as a designer of agricultural tractors for the Emerson-Brantingham Co., of Minneapolis. From the early part of 1913 to 1919 he served successively as designer of stationary gas engines for the Emerson-Brantingham Co., at Rockford, Ill.; designer and engineer on automatic engine-starters for W. A. Knapp, of Minneapolis; designer of a general line of machinery and stationary gas engines for R. R. Howell & Co., of Minneapolis; assistant chief engineer and designer of four-cylinder agricultural tractors for the Mayer Brothers Co., of Mankato, Minn.; and as chief draftsman for the Fergus Motors of America, in Newark, N. J.

During the World War Mr. Elfes served his Country as an aeronautic engineer with the Signal Corps of the Army. For three years following the armistice he worked as an independent designing engineer in Detroit, but in 1921 was engaged by the L.B.D. Engineers, of that city, as chief engineer. He held this same position for the next seven years and then joined the Motor Products Corp. as sales engineer.

Carl H. L. Flintermann

THE MANY friends and acquaintances of Carl H. L. Flintermann were greatly shocked by reports of his untimely death on Jan. 18 at the Hayes Hotel in Jackson, Mich.

Mr. Flintermann was president of the Wilcox-Rich Corp., of Detroit, a position he had held since his election to it in 1928. He had been an Associate Member of the Society since May, 1919.

Born at Detroit in 1876, Mr. Flintermann, after attending the grammar and high schools, started in business life in a local hardware store, but shortly went to work for the Union National Bank of Detroit. The following four years were spent in this bank and the Commercial Bank of Detroit. For eight years, beginning in 1897, he was connected with the Library Bureau of Boston, engaged in establishing branches in various parts of the United States and Canada. His entry into the mechanical manufacturing field was made in 1905, when he became vice-president and manager of the Universal Adding Machine Co., of St. Louis. After four years in this connection, he joined the Baker-Young Co., of Boston, and its affiliated New England power companies.

Mr. Flintermann's association with the automotive industry began in 1913, when he was elected managing vice-president of the Detroit Pressed Steel Corp. and began promoting the development of Disteel wheels. After 10 years with this company he became vice-president of the Michigan Steel Casting Co. and president of the Flintlock Corp., of Detroit. His next and last change was to the presidency of the Wilcox-Rich Corp. in 1928.

During the World War Mr. Flintermann was chairman of the pressed-steel division of the War Industries Board.

Besides holding membership in the Society and the Detroit Section of the S.A.E., he was a member of a number of athletic and sports clubs in and near Detroit, of the Detroit Rotary Club and the Lake Placid Club.

Yu Tsao Barr

A PROMINENT foreign naval and aircraft Associate Member of the Society—Yu Tsao Barr, director and chief engineer of the Naval Air Establishment of the Chinese Navy, at Foochow, China—passed away on Dec. 20, 1930.

Mr. Barr became a Junior Member of the Society in 1917, at which time he was an aeronautic engineer residing in Buffalo, N. Y. He was transferred to Associate grade in 1922.

Born at Chinkiang, China, in 1892, his Chinese name was Tsao Yu, but several years ago he added the English name, Barr. His technical education was acquired at Armstrong College, England, from 1911 to 1914, and at the Massachusetts Institute of Technology, where he studied mechanical engineering during 1915 and 1916. He held the degrees of Bachelor of Science and Master of Science from these institutions.

Mr. Barr's professional career began with Vickers & Co., Ltd., of Darrow-in Furness, England, which he served for one year as marine engineering draftsman. After being graduated from M. I. T. in 1916, he joined the Curtiss Aeroplane Co., of Buffalo, as aeronautic engineer in the research department. Returning to China in 1917, he was commissioned a lieutenant in the Chinese Navy and from 1920 to 1930 was stationed at the Government Dock in Fukien, being made officer in charge of the aircraft department of the Government Dock & Engineering Works at Fukien, China, in 1924. He remained in charge of this department until 1927, when he was made officer in command of the Naval Air Establishment of the Chinese Navy, at Fukien; then in 1929 was transferred to the Naval Air Establishment at Foochow, as director, the post he held until his recent death.

Lucius Morton Wainwright

BY THE passing away of Lucius M. Wainwright at his winter home at Miami Beach, Fla., on Feb. 24, following a long illness, the automotive industry has lost another of its pioneers and the Society one of its very early members.

Mr. Wainwright had been president of the Diamond Chain & Mfg. Co., of Indianapolis from 1905 to the time of his death and was very widely known in the automotive field. For more than 20 years he was treasurer of the Motor & Accessory Manufacturers Association. He was elected to membership in the Society in October, 1908, and retained his membership throughout the last 22 years. He was also a member of the Indiana Section since 1920. During the three years from 1918 to 1920, inclusive, he was Chairman of the Roller Chain Division of the Standards Committee, and in 1921 and 1923 he was a member of this Division.

Born in January, 1860, at Noblesville, Ind., Mr. Wainwright attended school there and, following an experience of 10 years in the designing and manufacturing of bicycles with the Central Cycle Co., from 1890 to 1899, devoted all the rest of his business life to designing and developing pitch chains for power transmission. He joined the Diamond Chain factory of the American Bicycle Co. in 1900 as designer of chains and of automatic tools for making and assembling them. He also devoted his energies to the improvement of sprockets and the conditions under which chains and sprockets operated. In 1905 he organized the Diamond Chain & Mfg. Co., which took over the bicycle company's chain factory and became its president and general manager.

Besides holding the presidency of the Diamond Chain & Mfg. Co., Mr. Wainwright was a director of the Fletcher American National Bank, the Morris Plan Co. and the Wainwright Trust Co., in Noblesville. He was a member of the American Society of Mechanical Engineer and of the Indianapolis Athletic Club, the Columbia Club, the Highland Golf and Country Club, the New York Yacht Club, the Manhattan Bay Yacht Club, the Surf Club of Miami and the Question Club.

Personal Notes of the Members

S. A. E. Members Elected Directors of Aeronautical Expositions Corp.

Among the 15 directors for the ensuing year elected at the annual meeting of stockholders of the Aeronautical Expositions Corp., held in New York City on March 10, were the following eight members of the Society of Automotive Engineers:

J. R. Cautley, of the Bendix Brake Co.; C. H. Colvin, of the Pioneer Instrument Co.; E. L. Cord, of the Stinson Aircraft Co. and president of the Auburn Automobile Co.; Charles L. Lawrance, of the Lawrance Engineering & Research Corp.; R. B. C. Noorduyn, of the Bellanca Aircraft Co.; P. G. Johnson, of the Boeing Airplane Co.; J. M. Schoonmaker, Jr., of the General Aviation Corp. and the Fokker Aircraft Co.; and Guy W. Vaughan, of the Wright Aeronautical Corp.

Mr. Cautley and Mr. Colvin are members of the Society's Aircraft Division of the Standards Committee and both have presented papers at meetings of the Society. Mr. Lawrance has presided at sessions of National Aeronautic Meetings and Mr. Schoonmaker has presented papers at National meetings. The directorate of the Aeronautical Expositions Corp. reflects the close tie-up of the S.A.E. with the aeronautic industry.

Keys Leaves U. S. Rubber Co.

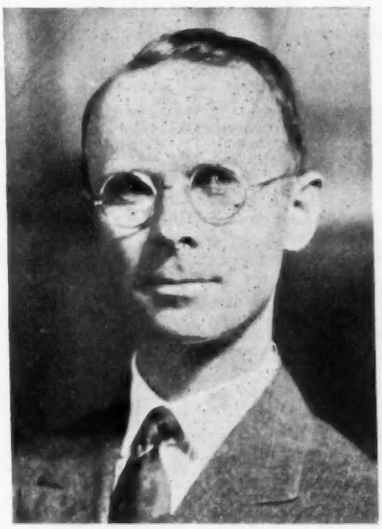
After having served the United States Rubber Co., of Detroit, for the last four years as manager of automotive development in the mechanical rubber division, Walter C. Keys has severed this connection and opened an office of his own in the Stephenson Building, Detroit, where he will pursue automotive engineering and sales work.

Virtually all of Mr. Keys' business life has been devoted to the automotive industry, as he spent six months in the chassis assembly department of the Buick Motor Co. in 1905, although he was not graduated from the University of Michigan with the degree of Bachelor of Science in Electrical Engineering until 1907. From 1908 to 1909 he was instructor in manual training in the Cincinnati public schools, and he next spent one year in designing and detailing in the drafting room of the Cadillac Motor Car Co., one year in charge of the drafting room of the Chalmers Motor Co., and one year in designing, testing and inspecting for the Church-Field Motor Co. For the succeeding three years he was assistant chassis engineer for the Cadillac Motor Car Co., specializing on springs.

Thereafter he was successively mechanical engineer with the Perfection Spring Co., of Cleveland; assistant to the director of engineering and development engineer of the Standard Parts Co., of Cleveland; plant engineer of the Eaton Axle Co., of Cleveland; manager of the Cincinnati axle plant of the Standard Parts Co.; manager of the Gabriel Snubber Sales & Service Co., of Detroit, and Detroit representative of the Gabriel Mfg. Co.

Mr. Keys formed his connection with the United States Rubber Co. first in 1926, when he became chief engineer of the mechanical automotive department at Detroit, the position he held for four years until his recent resignation.

Since his election to Member grade in 1915, Mr. Keys has been very active



WALTER C. KEYS

in committee work in the Society, having been in the last 14 years a member of the Springs Division, Miscellaneous Division, and Parts and Fittings Division of the Standards Committee; Chairman of the Parts and Fittings Division for three years; a member of the Membership, Sections, and Motor-Vehicle Committees; Vice-Chairman of the Passenger-Car Committee and a member of the Riding-Qualities Subcommittee of the Research Committee. He has been a member of the Detroit Section ever since joining the Society 15 years ago, was Treasurer of it in 1924 and now represents it on the Sections Committee. He was also for several years a member of the Cleveland Section.

In 1917 Mr. Keys presented a paper on Spring Design for Easy Riding before the Pennsylvania Section, which was printed in THE JOURNAL for December of that year, p. 366, and reprinted in TRANSACTIONS for 1917, part 2, p. 454. The following year he gave a paper on Factory Inspection before the Cleveland Section which was printed in THE JOURNAL for October, 1918, p. 266.

Alfaro Goes with Autogiro

Heraclio Alfaro became special representative and consulting engineer of the Autogiro Co. of America, of Philadelphia, with the beginning of the present year. For the years 1929 and 1930 he was owner of H. Alfaro Aeronautical Engineering, of Cleveland. He has been a member of the Society and of the Cleveland Section from 1928. In 1929 he presented before the Milwaukee Section a paper entitled, Possible Improvement of Present-Day Aircraft, which was published in the S.A.E. JOURNAL for September, 1929, p. 207, and reprinted in TRANSACTIONS for 1929, p. 390.

White Starts Boat-Design School

Gerald Taylor White has severed his connection as editor of *Motor Boat* in New York City and opened the Westlawn School of Home Study at Montville, N. J., to conduct a correspondence course in boat designing. He will also continue the work of personally designing boats and writing technical papers on boat designing and marine engineering.

Mr. White has been associated with boat work for the last quarter century, having been connected from 1905 to 1910 with the Consolidated Shipbuilding Co., of New York City, as a boat builder in the woodworking department, and for the following 10 years engaged in private practice as a consulting naval architect.

From 1920 to 1928 he was editor of *Rudder*, in New York City, and from 1918 to 1922 was also instructor in yacht and ship design at the Cooper Union Night School. In 1928 he gave up his editorial work to become chief engineer of the small-boat division of the Fairchild Airplane Corp., of New York City, but the following year became editor of *Motor Boat*.

Mr. White was elected to Member grade in the Society in 1924 and also joined the Metropolitan Section in that year.

Preble Joins S.P.A. Truck Corp.

T. L. Preble, assistant general manager of the Brockway Motor Truck

(*Continued on p. 52*)

Applicants Qualified

The following applicants have qualified for admission to the Society between Jan. 10 and March 10, 1931. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALMSTEAD, CHARLES W. (A) European representative, Warner Electric Brake Corp., Beloit, Wis.; president, Modern Chemical Mfg. Co., Inc., Dallas, Texas; (mail) 1406 Republic Bank Building, *Dallas, Tex.*

ARMER, JAMES C. (A) vice-president, Dominion Forge & Stamping Co., Ltd.; Canadian Motor Lamp Co., Ltd., East Windsor, Ont., Canada; (mail) 105 Victoria Street, *Toronto, Ont., Canada.*

AUSTIN, CALVIN TULLER (A) engineer, 3617 Sierra Vista Avenue, *Glendale, Calif.*

BAKER, BRYANT E. (A) assistant sales manager, lubricating oil department, Standard Oil Co., *New York City;* (mail) 3349 Decatur Avenue.

BEACH, HARRY L. (J) Standard Oil Co. of New York, Hartford, Conn.; (mail) *Bristol, Conn.*

BLACK, HARRY DAVIS (J) junior engineer, training course, Buda Co., *Harvey, Ill.;* (mail) 15233 Turlington Avenue.

BOCKSRUKER, AL. F. (J) draftsman, Allis-Chalmers Mfg. Co., *Milwaukee;* (mail) 1434 South 34th Street.

BOULT, C. M. G. D. (F M) sales manager, truck department, John McGrath, Ltd., 181 Elizabeth Street, *Sydney, New South Wales, Australia.*

BRADY, GEORGE F. (M) foreman, service and experimental, Kinner Airplane & Motor Corp., *Glendale, Calif.;* (mail) 432 South Pacific Avenue.

BROWNING, KENDALL COLIN (F M) professor of chemistry and metallurgy, Chemistry Branch, Military College of Science, Woolwich, S. E., 18, *London, England.*

BRULL, CHARLES BERNARD (F M) director of Citroen laboratories, Citroen Cars Co., 139 Quai de Javel, *Paris* (15e) *France.*

BUTTERBAUGH, HOMER W. (M) technical supervisor, American Brass Co., Kenosha Branch, *Kenosha, Wis.*

CHAMP, KENNETH B. (A) president, general manager, Lincoln Oil & Paint Co., 1205 East 55th Street, *Cleveland.*

CHENAULT, ROY L. (J) engineer, Gulf Production & Pipe Line Co., 327 Craft Avenue, *Pittsburgh.*

CLINE, M. W. (A) president, general manager, Dart Truck Co. of Missouri, 2648 Oak Street, *Kansas City, Mo.*

COBLE, J. B. (A) welding foreman, instructor, inspector, E. H. Lanier, Covington, Ky. (mail) 546 East Fourth Street, *Newport, Ky.*

COHEN, MORRIS (M) industrial engineer, in charge of delivery equipment, all buildings, other equipment, Schulze Baking Co., 118 West 47th Street, *Kansas City, Mo.*

COMER, MELVIN ROSS (J) special representative, industrial tractor division, J. I. Case Co., Racine, Wis.; (mail) 139 Mitchell Street, *West Orange, N. J.*

CONDAK, EDWARD (M) layout draftsman, Chevrolet Motor Co., *Detroit;* (mail) 1565 Davison Avenue.

COOKE, EDWARD FRANCIS (A) used-car manager, General Supplies, Ltd., *Calgary, Alberta, Canada;* (mail) Suite 5, Kensinger Apartments, 12th Street, Hillhurst, Calgary.

CRAWFORD, EDWIN GAIL (A) sales engineer, Gramm Motors, Inc., Delphos, Ohio; (mail) *Doylestown, Pa.*

DALTON, RICHARD (J) inspector, Wright Aeronautical Corp., Paterson, N. J.; (mail) 139 Prescott Avenue, *Hawthorne, N. J.*

DAVIES, FREDERICK DETHERIDGE (F M) partner, working in all branches, J. Davies & Sons, Box 145, *Rotorua, New Zealand.*

DEY, ANTHONY ROBERT (M) engineer, experimental laboratory, Safety Car Heating & Lighting Co., New Haven, Conn.; (mail) 48 Goodyear Avenue, *Naugatuck, Conn.*

FARRAR, EARL V. (J) designer, Wright Aeronautical Corp., Paterson, N. J.; (mail) 165 Franklin Street, *Bloomfield, N. J.*

FARRIS, CLAYTON (M) president, Trucktor Corp., 156 Wilson Avenue, *Newark, N. J.*

FORD, WATSON I. (J) field engineering department, tire development division, United States Rubber Co., 6600 Jefferson Avenue, *Detroit.*

GODFREY, EDWIN H. (M) project engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) 71 Oakwood Avenue. *Upper Montclair, N. J.*

GOOSTRAY, JOSEPH (M) mechanical engineer, Hunt-Spiller Mfg. Corp., 383 Dorchester Avenue, *South Boston, Mass.*

GROSS, C. HEINZ (J) layout draftsman, Trico Products Corp., *Buffalo;* (mail) 1154 Kenmore Avenue.

GUERRITORE, ORAZIO, COL. (F M) consulting expert on motor fuels and antiknock agents, Societa Italo-Americana del Petrolio, Genoa, Italy; (mail) Piazza Poli, No. 37, *Rome, Italy.*

HALL, ALBERT LEO (A) parts superintendent, White Co., 458 Melwood Street, *Pittsburgh.*

HALL, ROBERT C. (M) engineering aid, United Railways & Electric Co., Carroll Park Shops, *Baltimore.*

HARDING, LOWELL S. (M) superintendent AM 19, in charge of operations, New York to Atlanta air-mail and passenger route, Eastern Air Transport, Inc., Brooklyn, N. Y.; (mail) Apartment 12, 515 North Boulevard, *Richmond, Va.*

HASLAM, R T. (M) vice-president, general manager, Standard Oil Development Co., 26 Broadway, *New York City.*

HENKEL, JOACHIM (M) experimental engineer, Chrysler Corp., Engine Division, *Detroit;* (mail) 111 Highland Avenue.

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WYNNE, CHARLES HORACE L. (F M) chief engineer, Stromberg Motor Devices, Ltd., 106 Cheyne Walk, *London, S. W. 10, England.*

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Applicants for Membership

The applications for membership received between Feb. 16 and March 16, 1931, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALBERT, FRANCIS, salesman, Sterling Motor Truck Co., *Baltimore.*

ARMITAGE, LAURENCE CHEYNE, consulting engineer, Cheliabinsk Tractor Plant, *Cheliabinsk, U.S.S.R.*

ARNER, GEORGE R., service manager, Commander Motors, Inc., *Paterson, N. J.*

BECK, WILLIAM HENRY, automotive and industrial engineer, Sherwood Bros., Inc., *Baltimore.*

BLACKMER, W. H., sales manager, Laminated Shim Co., Inc., *Long Island City, N. Y.*

BOYLE, CHARLES EDWIN, field representative, Ethyl Gasoline Corp., *New York City.*

BROWN, RAY WALTER, regional aviation representative, Shell Petroleum Corp., *Chicago.*

BUCHMANN, LOUIS, designer, Buffalo Scale Co., *Buffalo.*

BURGHDUFF, ERNEST C., sales engineer, Glenn L. Martin Motor Co., *Baltimore.*

BURN, LEWIS, managing director and consulting engineer, Burn Transmissions, Ltd., *Longparish, Hants, England.*

BURNHAM, C. A., manager and chief engineer, Aircraft Sheet Metal Co., *Wichita, Kans.*

BUTERA, CHARLES N., student training course, mechánical engineer, Kings County Buick, Inc., *Brooklyn, N. Y.*

DAVIDS, JOHN, designer, Johnson Motor Co., *Waukegan, Ill.*

DAY, O. E., chief chemist, in charge of all laboratory work, Root Refining Co., *El Dorado, Ark.*

DOUGLASS, EDGAR, draftsman, Duquesne Light Co., *Pittsburgh.*

EVANS, F. D., partner, Paul H. Davis & Co., *Chicago.*

FRENCH, RALPH W., Hawaiian Division, Quartermaster Trains, Quartermaster Corps, U.S.A., *Honolulu, T. H.*

GATKE, THOMAS L., president and treasurer, Gatke Corp., *Chicago.*

GOMBINSKI, JOSEPH, plant engineer, F. A. Isotta Fraschini, *Milan, Italy.*

GRACCHI, CELESTINO LOUIS, stress analyst, Keystone Aircraft Corp., *Bristol, Pa.*

GRIFFIN, J. CLIFF, superintendent, Coulter Copper & Brass Co., Ltd., *Toronto, Ont., Canada.*

HAWLEY, FRANK O., mathematician, International Harvester Co., *Fort Wayne, Ind.*

HALLADAY, HOLLIS P., sales engineer, United States Pressed Steel Co., *Kalamazoo, Mich.*

HIBRI, KHALIL, partner and general manager Hibri Ayas Automotive Co., *Beyrouth, Syria.*

HOLT, GLEN GROVER, general manager, Hannum Mfg. Co., *Milwaukee.*

KITCHELL, CHARLES H., aeronautical engineer, Jacobus Engineering Co., *Cleveland.*

LISTER, FRANK HERBERT, director in charge of works, R. A. Lister & Co., Ltd., *Dursley, England.*

MCADAM, FREDERICK EDWARD, European district manager, Firestone Tire & Rubber Co., *Vienna, Austria.*

NOONAN, EDMUND L., military service engineer, Curtiss Aeroplane & Motor Co., *Buffalo.*

POOLE, HARRY E., service representative, General Motors of Canada, Ltd., *London, Ont., Canada.*

PRIME, NATHANIEL S., Lieut., U.S.N., Navy Department, *City of Washington.*

RIEGER, EARL C., assistant chief engineer, gas power laboratory, International Harvester Co. Tractor Works, *Chicago.*

RITTER, HAROLD J., assistant secretary, Norma Hoffmann Bearings Corp., *Stamford, Conn.*

ROYER, LLOYD G., president, engineer, Aero Engineering & Advisory Service, Inc., *New York City.*

RUSSELL, DAVID WARREN, vice-president and general manager, Southwestern Transportation Co., *Texarkana, Tex.*

SAVAGE, GEOFFREY HERBERT, production manager, Rover Car Co., Ltd., *Coventry, England.*

SAYRE, C. H., sales engineer, Willys Morrow Co., *Elmira, N. Y.*

SILVA-NETTO, ANTONIO, motorcoach maintenance engineer, Hong Kong Hotel Garage, Stubbs Road, *Hong Kong, China.*

SNYDER, W. OVERTON, divisional engineer, Pan American Airways, Inc., *Miami, Fla.*

SUDDES, ARTHUR S., chief engineer and works manager, Aero Engines of Canada, Ltd., *Montreal, Que., Canada.*

VERNON, WALTER G., finishing-mill engineer, Scott Paper Co., *Chester, Pa.*

WEBER, J. P., representative, Bendix Westinghouse Auto Air Brake Co., *Pittsburgh.*

WITTER, ERNEST J., Cleveland district service manager, The White Co., *Cleveland.*

Notes and Reviews

AIRCRAFT

An Extended Theory of Thin Airfoils and Its Application to the Biplane Problem. By Clark B. Millikan. Report No. 362. Published by the National Advisory Committee for Aeronautics, City of Washington, 33 pp., 16 figs. [A-1]

This paper gives a new treatment, due essentially to von Karman, of the problem of the thin airfoil. The standard formulas for the angle of zero lift and zero moment are first developed and the analysis is then extended to give the effect of disturbing or interference velocities, corresponding to an arbitrary potential flow, which are superimposed on a normal rectilinear flow over the airfoil.

An approximate method is presented for obtaining the velocities induced by a two-dimensional airfoil at a point some distance away. In certain cases this method has considerable advantage over the simple "lifting line" procedure usually adopted. The interference effects for a two-dimensional biplane are considered in the light of the previous analysis. The results of the earlier sections are then applied to the general problem of the interference effects for a three-dimensional biplane, and formulas and charts are given which enable the characteristics of the individual wings of an arbitrary biplane without sweepback or dihedral to be calculated.

In the final section the conclusions drawn from the application of the theory to a considerable number of special cases are discussed, and curves are given that illustrate certain of these conclusions and serve as examples to indicate the nature of the agreement between the theory and experiment.

Dynamic and Flight Tests on Rubber-Cord and Oleo-Rubber-Disc Landing-Gears for an F6C-4 Airplane. By William C. Pack. Report No. 366. Published by National Advisory Committee for Aeronautics, City of Washington, February, 1931, 19 pp. [A-1]

This investigation was conducted by the National Advisory Committee for Aeronautics, at the request of the Bureau of Aeronautics of the Navy Department, for the purpose of comparing an oleo-rubber-disc and a rubber-cord landing-gear built for use on an F6C-4 airplane. The investigation consisted of drop tests under various loading conditions and flight tests on an F6C-4 airplane. In the drop tests the total work done on each gear and the work done on each of the shock-absorbing units was determined. The maximum loads and accelerations were determined for both drop tests and flight tests.

The comparative results showed that the oleo gear was slightly superior in reducing the ordinary landing shocks, that it had a great capacity for work and that it was very superior in the reduction of the rebound. The results further showed that, for drops comparable to very severe landings, the rubber-cord gear was potentially more effective as a shock-reducing mechanism. However, because of the construction of this chassis, which limited the maximum elongation of the cords, this gear was incapable of withstanding as severe tests as the oleo gear. The action of the oleo gear during the tests was greatly inferior to the action of an ideal gear. The maximum accelerations encountered in the flight tests for severe landings were $3.64g$ for the rubber-cord gear and $2.27g$ for the oleo gear. These were less than those experienced in free drops of 7 in. on either gear.

The McCallum-Peters Six-Element Telemeter Strain-Gage Set. Prepared by Charles J. Spere. Technical Report No. 3313. [A-1]

Test of Armstrong-Whitworth Steel Spars under Combined Axial and Transverse Loading. Prepared by C. G. Brown. Technical Report No. 3296. [A-1]

The foregoing Technical Reports were published by the Chief of the Air Corps, City of Washington, December, 1930.

Pressure Distribution over a Thick, Tapered and Twisted Monoplane Wing Model—N. A. C. A. 81-J. By Carl J. Wenzinger. Report No. 367. Published by the National Advisory Committee for Aeronautics, City of Washington, February, 1931, 16 pp. [A-1]

This report presents the results of pressure distribution on a thick, tapered and twisted monoplane-wing model. The investigation was conducted for the purpose of obtaining data on the aerodynamic characteristics of the new wing and to provide additional information suitable for use in the designing of tapered cantilever wings. The tests included angles of attack up to 90 deg. and were made in the atmospheric wind-tunnel of the National Advisory Committee for Aeronautics.

The span loading over the wing was approximately of elliptical shape, which gave rise to relatively small bending moments about the root. The angle of zero lift for all sections along the span varied only within ± 0.4 deg. of the angle of zero lift for the whole wing, resulting in small leading-edge loads for the high-speed condition of flight. The results also add to the available information for the study of stability at large angles of attack.

The Behavior of Conventional Airplanes in Situations Thought to Lead to Most Crashes. By Fred E. Weick. Technical Note No. 363. [A-1]

Tests in the Variable-Density Wind-Tunnel to Investigate the Effects of Scale and Turbulence on Airfoil Characteristics. By John Stack. Technical Note No. 364. [A-1]

Interference Effects and Drag of Struts on a Monoplane Wing. By Kenneth E. Ward. Technical Note No. 365. [A-1]

Torsion in Box Wings. By John B. Wheatly. Technical Note No. 366. [A-1]

The Aerodynamic Characteristics of Three Tapered Airfoils Tested in the Variable-Density Wind-Tunnel. By Raymond F. Anderson. Technical Note No. 367. [A-1]

The foregoing Technical Notes were issued during February, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

(*Continued on next left-hand page*)

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the auotmotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3. Miscellaneous; 4, Operation; 5, Production; 6, Sales.

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Continued

Flat-Sheet Metal Girder with Very Thin Metal Web. By Herbert Wagner. Technical Memoranda Nos. 604, 605 and 606. Part I, General Theories and Assumptions. Part II, Sheet-Metal Girders with Spars Resistant to Bending—Oblique Uprights—Stiffness. Part III, Sheet-Metal Girders with Spars Resistant to Bending—The Stress in Uprights—Diagonal Tension Fields. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Vol. 20, Nos. 8, 9, 10, 11 and 12, May and June, 1929. [A-1]

The Aerodynamic Wind-Vane and the Inherent Stability of Airplanes. By A. Lapresle. Technical Memorandum No. 607. Translated from Bulletin Technique of the Services Techniques de L'Aeronautique No. 66, February, 1930. [A-1]

The foregoing Technical Memoranda were issued during February, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Metal Gained Over Other Materials in Airplane Construction in 1930. By W. A. Kirkpatrick. Published in *Automotive Industries*, Feb. 7, 1931, p. 192. [A-1]

From information supplied by manufacturers for publication in the 1931 Chilton Aero Directory and Catalog and in the statistical issue of *Automotive Industries*, the author has prepared this analysis of 1931 aircraft productions. Specifications of 129 models in production in the United States and of 45 models produced abroad were considered.

The year 1930, instead of having been one of record production, was a year of arduous development, experiment and improvement, declares the author.

The cost of operation of the large passenger airplanes is believed to be responsible for the trend toward smaller planes flown on a more frequent schedule. During the year the two-place plane gained the ascendency over the three-place plane, and, with the progress toward the elimination of wing flutter, there is a tendency toward monoplanes.

Metallurgical laboratories played a peculiarly significant part in the progress of aeronautic engineering during the year 1930, and metal is gaining in favor over laminated wood in plane structures. Fuselages of aluminum-alloy construction have increased from 12 per cent of all models in 1930 to 20 per cent this year. The trend toward the use of metal in wing construction is more significant, foreign practice showing more definitely the trend toward metal in wings, as a considerable proportion of the European airplanes have metal wing-ribs and metal spars. Fabric is not giving much ground to metal as a wing covering and remains dominant as a covering for the fuselage. America, however, apparently is far ahead of foreign countries in the use of metal propellers.

Brakes on the undercarriage wheels are fast becoming standard equipment, and batteries are standard equipment on 83 out of 114 models.

In conclusion, the author points out that much of the designing effort during 1930 was devoted to "cleaning up" the ships—streamlining or recessing parts exposed to the airstream, experimenting with retractable landing-gears and even with retractable wing fittings and so forth.

Der DVL-Torsiograph, ein Drehschwingungs-Massgerät für Fahrzeugmotoren. By Albert Stieglitz. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 28, 1931, p. 49. [A-1]

An apparatus for measuring and recording during flight the torsional vibration of the crankshaft of an aircraft engine is herein described. Developed by the German Institute for Aeronautical Research, the instrument records the vibrations in their natural amplitudes by means of a dia-

(*Continued on next left-hand page*)

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mond marking on a celluloid strip. The diagrams may then be studied with the aid of a microscope.

The torsiograph, as the instrument is called, may be built onto the crankshaft and runs freely with the shaft. Its operation is said to be simple and such as can be easily attended to by the pilot in flight. The records, according to the claims made, are free from inertia effects and accurate even in the highest frequencies. Engine speed is also indicated on the record.

The article describes the instrument, its mounting and operation and gives an example of the records obtained.

Widerstand und Kühlwirkung eines Flugzeugrumpfes mit verschieden angeordnetem Kühler. By H. Muttray. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 14, 1931, p. 65. [A-1]

The scope of the investigation on aircraft radiators herein recorded was definitely limited to aerodynamic aspects. It was still further narrowed by leaving out of consideration everything except the radiator and the fuselage.

Answers were sought to two questions: where should the radiator be mounted? and how should the cooling blast be directed to secure the necessary cooling effect and at the same time avoid increasing the drag? Wind-tunnel measurements were made on models of radiators and fuselages to determine the aerodynamic efficiency of the radiator and the drag of the fuselage with and without the radiator. Results are given of the tests on a nose radiator and an underslung radiator, with various cowling and vent arrangements. Values for other types of radiator were obtained and will be reported in a future publication.

Berechnung von Luftschrauben und Vergleich mit Versuchsergebnissen. By R. Seiferth. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 14, 1931, p. 73. [A-1]

Commenting on the propeller theory as developed by Betz, Prandtl, Karman, Bienen, Helmbold and others, the author asserts that it covers adequately only propellers with small thrust. He points out a number of simplifications on which it is based and works out another system of propeller calculations. Reports are then given of wind-tunnel tests made on six model propellers, three of modern light-alloy construction and three of wood. Measurements were made at constant turning speed and varying wind-speed. These test results are compared with calculated results and directions are given for the modification of the calculations to forecast accurately the experimental findings.

L'Aéronautique de 1880 a 1930. By R. Soreau and A. Volmerange. Published in *Le Génie Civil*, November, 1930, p. 16. [A-1]

Aircraft have been less the product of definite inventions than the result of progress in every branch of engineering, asserts the author in introducing his summary of aviation from 1880 to 1930. This article is one of 42 brief histories, each dealing with a different technical field, published in the November, 1930, fiftieth anniversary number of *Le Génie Civil*.

Dealing first with lighter-than-air craft, the author traces their development through the rigid type, as exemplified by the Graf Zeppelin, and raises a question as to the utility of these giant ships, which represent so heavy an investment in construction, handling and housing costs and which seem unfortunately to be at the mercy of the elements. The airplane, called "the flower born of speed," seems to offer more promise. Its accelerated war development is mentioned, the succeeding long-distance flights across the Atlantic, toward Africa and toward the Far East are listed, world records are set forth and the aerodynamic principles involved in flight are briefly summarized.

(*Continued on next left-hand page*)

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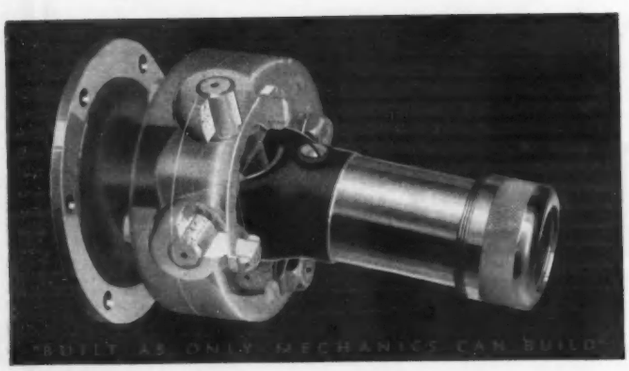

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Aircraft engines are contrasted with their progenitors, the automobile powerplants, special emphasis being laid on high compression-ratios and supercharging. One of the most essential requirements for the aircraft engine of the future is said to be the ability to use non-inflammable fuel.

The section dealing with aircraft materials mentions high-strength steels, light aluminum alloys and ultra-light magnesium alloys.

Bibliography of Aeronautics, 1929. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930, 242 pp. Price, 35 cents. **[A-3]**

This bibliography of aeronautics for 1929 covers aeronautic literature published from Jan. 1 to Dec. 31, 1929. Citations of the publications of all nations are included in the languages in which these publications originally appeared. The arrangement is in dictionary form, with author and subject entry, and one alphabetical arrangement.

It may be obtained directly from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Aviation Register. Published by Aviation Register, Chicago, 226 pp. Price, $2.00. **[A-3]**

This aeronautical directory is a storehouse of valuable information concerning American and foreign aviation. The main topics covered are accessories and equipment, air activities, airports, commercial aviation, executives and personnel, Government inspectors, medical examiners, and organizations.

Air activities are given alphabetically by States, while airports are listed by cities. The chapter dealing with executives and personnel is a veritable aviation Who's Who.

The Register is published three times yearly so as to keep it uptodate.

Jane's All the World's Aircraft, 1930. Compiled and edited by C. G. Grey and Leonard Bridgman. Published by Sampson Low, Marston & Co., Ltd., London, 588 pp. Price, 42 shillings. **[A-3]**

A cursory reading of this 20th edition of All the World's Aircraft reveals no startling evidence of aviation development but remarkable progress at the two extremes of aviation: in the high-speed fighting airplanes at one end and in light airplanes at the other end. The three outstanding performances of 1930 were: a speed exceeding 200 m.p.h. produced by a single-seat fighter, two-seat fighters and the Dornier Do-X, and the astonishing speed reached by the Schneider Trophy racers.

The book is arranged in five parts: aeronautical progress, historical, airplanes, aeronautic engines and airships. Everything is arranged alphabetically. If information is desired about military, naval or air-service flying in any country, the section devoted to that country can be turned up alphabetically more quickly than it can be looked up in the index.

On the civil side, airline work has been expanded in almost all countries except Germany, and even there it has been condensed rather than contracted.

Throughout the airplane section, the specifications have been reduced to a standard form, with English and metric measurements, which seems to be accepted all over the world. In the engine section no startling novelty is to be found, but study of the figures shows how remarkably power is increasing in proportion to weight.

In addition to technical information, the names and addresses of the aeronautic officials, departments, associations and publications of the various nations are given.

Like its predecessors, this edition is an unusual compilation of aeronautic information and is worthy of consideration.

(*Continued on next left-hand page*)

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And any wire wheel sparkles with the brilliance of stainless steel

BUDD SNAPSPOKES are one of those rare developments that come once in a long, long time. So simple that it's a wonder nobody ever thought of them before. So moderately-priced that every car owner can afford them. So in tune with what the public wants that they drop an opportunity for healthy profits right in your lap!

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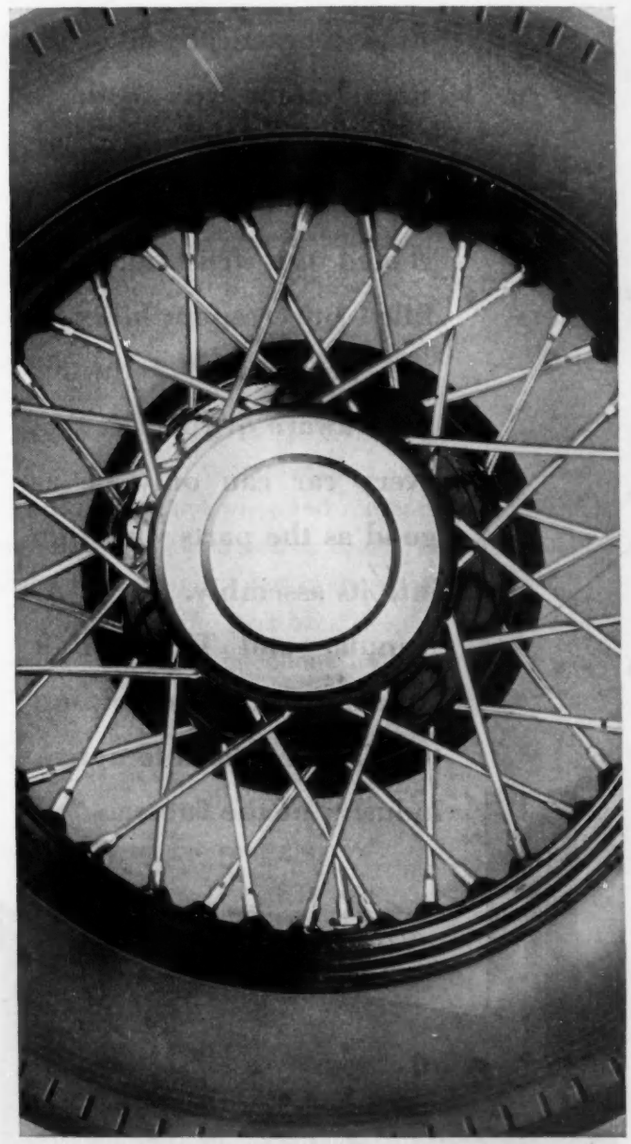
If you don't think this is one of the greatest little profit-pullers that ever came along, you'd better think again. Budd Snapspokes have stirred up tremendous enthusiasm. Dealers are finding that they put pep into the sale of new cars. Equip a car with Budd Snapspokes and you'll find that out in a hurry. You'll find, too, that they sell readily to present owners!

A set of Budd Snapspokes—for five wheels—cost no more than painting the wheels. Your profit is generous. Stocks available in principal cities.

Write or wire Budd Wheel Company, Detroit, Mich., for name of nearest distributors.



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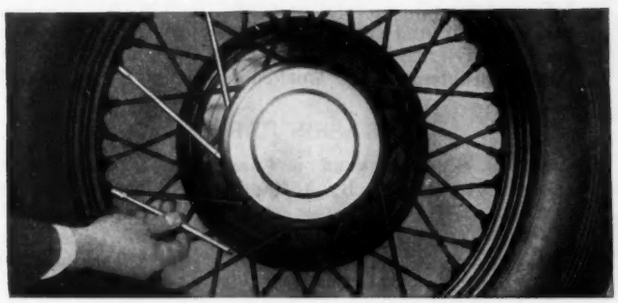
How new Snapspokes are installed. Just snap them on.



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Notes and Reviews

Continued

Preparing for Aviation. By Lieut. Volney C. Finch, U.S.N. (Retired). Published by the Simmons-Boardman Publishing Co., New York City, 1931; 458 pp. Price, $4.00. [A-3]

The author has had wide experience as a pilot and instructor and is a member of the S.A.E.

The book was prepared for use as an introductory text in a ground school, with special emphasis upon the airplane and its engine. It is thoroughly illustrated with drawings by the author and with photographs of all the latest types of American airplanes, engines and accessories. At the end of each chapter a list of references is given for further information.

It also furnishes the general reader a graphic exposition of the fundamental facts and newest approved training for a pilot's license. The last chapter is a list of the latest Department of Commerce examination questions for a pilot's license.

Growth of Aviation. By C. F. Fairey, F.R.Ae.S. Published in the *Journal of the Royal Aeronautical Society*, January, 1931, p. 4. [A-3]

Almost every country has some responsible body for dealing with technical research, testing or experimenting in aviation. Aeronautic research has grown with rapid strides so that today approximately 60 wind-tunnels are at work in the world, probably 9 tanks engaged on improvements in the hulls of flying-boats and seaplane floats, and, apart from private companies, aeronautic research of one kind or another is being pursued at 40 institutions.

Within the last 27 years the main items of performance have advanced as follows:

Distance, from 852 ft. to 4912 miles
Duration, from 59 sec. to 67 hr.
Altitude, from just clearing the ground to more than 43,000 ft.
Speed, from about 30 m.p.h. to 357 m.p.h.

Available statistics show that the regular world mileage is growing, the subsidy rate per mile is falling and such aviation is approaching a true commercial basis.

From its small beginnings early in this century, aviation covers today a distance of nearly 200,000,000 miles per year, not counting military aviation; more than 500,000 passengers, nearly 10,000 tons of goods and nearly 5000 tons of mail are carried annually on scheduled services alone; the industry is capitalized at almost $500,000,000 and gives employment to 70,000 persons. Yet the civil part of the industry is just beginning. These and many other interesting facts come to light in the information which Mr. Fairey has brought together.

Avigation. By Bradley Jones. Published by John Wiley & Sons, Inc., New York City, 1931, 314 pp. Price, $2.75. [A-4]

The methods of avigation described in this book are practical and have all been used in actual flight. Because there is a difference of opinion as to which is the best "short method" of working out astronomic observations, the chapter devoted to "short methods" describes several of these methods. The author works out the great circles slightly differently from the more standard procedure.

A few of the other avigation topics dealt with in the book are: magnetism and the compass, meteorology, fix by bearing, radio navigation, and fog flying. An interesting collection of problems to be worked out is given at the end of the book.

CHASSIS PARTS

Les Freins S. de Lavaud à Commande Hydraulique et Rélage Automatique. By A. Caputo. Published in *Omnia*, February, 1931, p. 601. [C-1]

The hydraulic brakes developed by S. de Lavaud are described in detail and the method of their installation is

(*Continued on next left-hand page*)

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Today, you can talk to any one of hundreds of thousands of telephone users for a fraction of what it then cost for connection with less than three hundred. Every new installation increases the scope and value of the telephones in your home or office.

Twenty-four hours of every day, the telephone stands ready to serve you in the ordinary affairs of life and in emergencies. In the dead of night, it will summon a physician to the bedside of a sick child. Men transact a great part of their business over it. Women use it constantly to save steps and time in social and household duties. In an increasing number of ways, it helps to make this a united, more active, more efficient nation.

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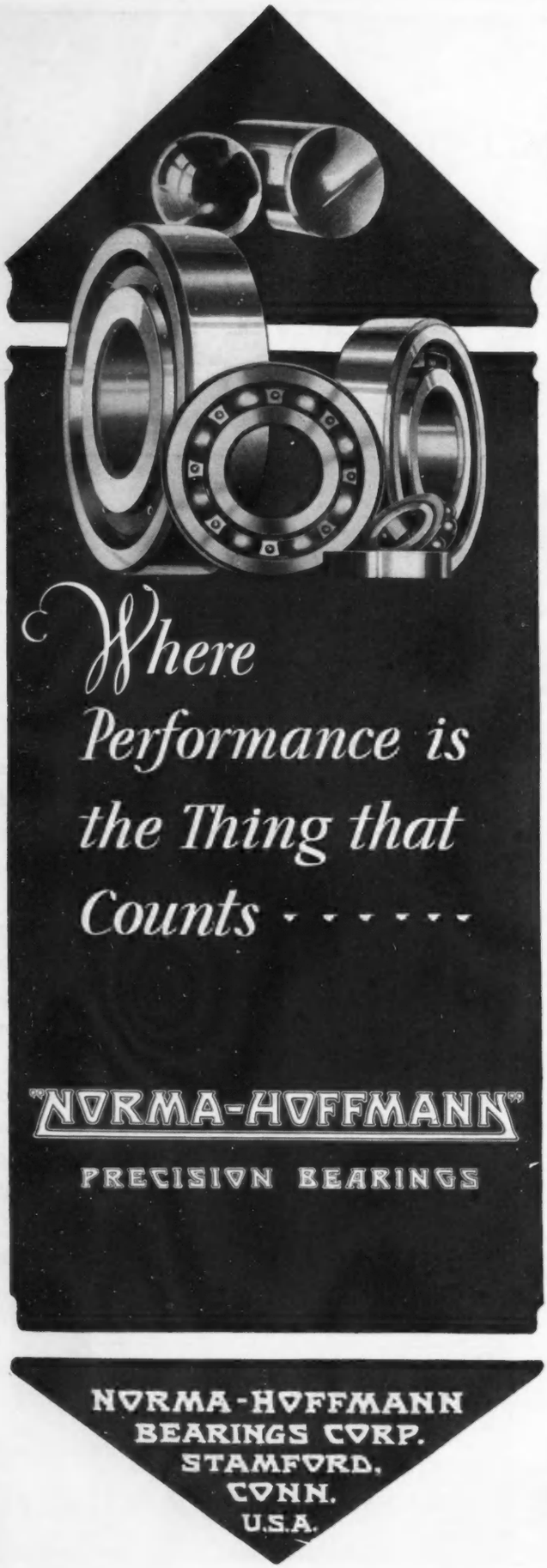
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Notes and Reviews

Continued

fully shown. The hydraulic circuit is stated to be entirely closed and so thoroughly leakproof as to render unnecessary any renewal of the liquid supply. Overheating is asserted to have been completely obviated, together with the evils consequent upon the dilation or vaporization of the liquid and the deterioration of the rubber used. The hookup is such that the driver can always feel the amount of pressure being exerted.

The drum assemblage is said to afford the minimum of wear, such wear being evenly distributed and automatically compensated for, assuring a useful pedal course unchanging in length and position.

Etude Théorique et Pratique des Embrayages à Disques. By M. Dufresne. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, January, 1931, p. 1218. [C-1]

In the theoretical section of his article on disc clutches the author develops methods of calculating the total clutch pressure and the inside diameter of the clutch facing, given the mamixum torque of the engine, the maximum diameter of the clutch, the coefficient of friction of the clutch facing and the permissible unit pressure.

The second section deals with the practical aspects of clutch design. In this the author discusses and compares the German, British and S.A.E. standards for clutch facings and quotes values found in practice in cars of today and of 1913 for the following factors: coefficient of friction of the brake-lining, unit clutch pressure, clutch-pedal pressure and pedal travel. He describes methods of attaching the clutch facing and of securing progressiveness of clutch action.

ENGINES

The Gaseous Explosive Reaction—The Effect of Pressure on the Rate of Propagation of the Reaction Zone and upon the Rate of Molecular Transformation. By F. W. Stevens. Report No. 372. Published by the National Advisory Committee for Aeronautics, City of Washington, February, 1931. [E-1]

A study of the gaseous explosive reaction, the source of power in gas engines, has been in progress at the Bureau of Standards for a number of years as one of the projects undertaken at the request and with the support of the National Advisory Committee for Aeronautics. In a report on this work recently released, the effect of pressure on the rate of propagation of the explosive reaction zone and on the rate of energy liberation during the progress of the reaction is considered from a physico-chemical standpoint.

The extensive experimental data on which the report is based are drawn from the explosive reactions of a large number of fuels, covering reaction orders from 3 to 15. During their reaction these fuels were subjected to wide ranges of pressure and of other physical conditions usually imposed on the reaction by its industrial application.

As a result of these studies, a number of important characteristics of the explosive reaction have been brought out which indicate that the basal processes of the transformation are much simpler and correspond more closely to the general laws and principles of ordinary transformations than is usually supposed.

Spark-Timing Control Actuated by Pressure in Engine Cylinder. By P. M. Heldt. Published in *Automotive Industries*, Feb. 14, 1931, p. 222. [E-1]

A new method of spark control, together with a related method of throttle and choke control, has been worked out by Warren F. Stanton, of Pawtucket, R. I. Mr. Stanton employs the pressures occurring in one cylinder of a multiple-cylinder engine to effect the control.

The device employed, as described in this article, is somewhat related to the so-called "point-by-point" engine indi-

(*Continued on next left-hand page*)

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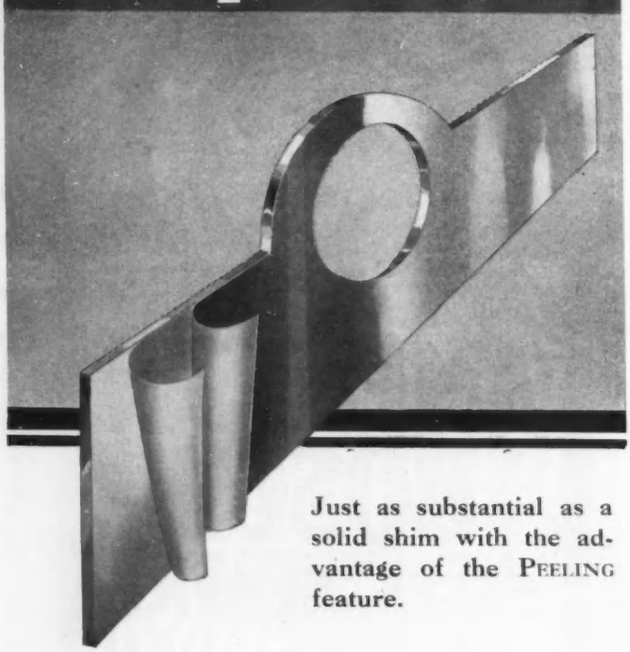

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LAMINUM

Notes and Reviews

Continued

cator, in that it places opposite ends of a control cylinder in communication with the engine cylinder at different points of the power stroke during each cycle.

Among the advantages claimed for this method of timing the spark automatically are that it increases engine power, reduces fuel consumption, lessens trouble from "pinging" and decreases the frequency of need for decarbonizing.

Aluminiumguss im Dieselmotorenbau. By W. Hartl. Published in *Automobiltechnische Zeitschrift*, Feb. 16, 1931, p. 94. [E-1]

In attempting to approach the ratio of weight to horsepower of the carburter engine, states the author, the designer of the Diesel engine is confronted with a difficult problem, since he must provide in his structure sufficient strength to resist high stresses. To builders desiring to use aluminum castings as a means for achieving weight reduction, he gives a few indications as to correct construction methods for highly stressed parts.

The physical characteristics peculiar to aluminum make careful designing imperative; in particular the greater modulus of elasticity necessitates special provisions for securing rigidity of structure. The author shows designs suitable for steel and aluminum castings for various parts, emphasizes the desirability of equal strength distribution and warns against too great reduction in weight. A second part of the article deals with the selection of suitable casting alloys.

L'Utilisation des Combustibles Lourds dans le Moteur à Explosion. By M. Gautier. Published in *La Technique Moderne*, Feb. 15, 1931, p. 119. [E-1]

Non-volatile fuels present too many difficulties to successful operation of explosion engines to render their use practicable, even in view of the interesting results given by the so-called chemical carbureters. Such fuels can be profitably utilized only in Diesel engines operating on a mixed cycle.

This is the conclusion drawn by the author after a study of the speed of flame propagation of various types of carbureted mixture, a simple homogeneous mixture, a simple mixture in which the fuel is insufficiently vaporized and a complex mixture containing non-volatile constituents. He emphasizes the importance of such fuel characteristics as spontaneous-ignition temperature and the volatility curve, and classifies liquid fuels according to their usefulness in explosion engines, considering, in addition to these two characteristics, viscosity, specific-heat value and ability to burn smoothly at high compression-pressures.

Thermostatic Control of Crankcase Oil Is a Much-Needed Development. By A. E. Becker. Published in *Automotive Industries*, March 7, 1931, p. 401. [E-4]

This is a slightly condensed edition of a paper presented by Dr. Becker at the Feb. 10, 1931, meeting of the Society's New England Section, a news summary of which appeared on p. 292 of the March, 1931, issue of the S.A.E. JOURNAL.

MATERIAL

The Proceedings of the American Society for Testing Materials, Vol. 30, 1930. Price, each part, $6.00 in paper, $6.50 in cloth, $8.00 in half-leather binding. This volume is issued in two parts. [G-1]

Part I (1336 pages) contains the annual reports of 48 standing committees, research committees and 4 sectional and joint committees of the society. Tentative standards, tables of data on chemical compositions, physical and mechanical properties, and corrosion-resistant properties of corrosion-resistant and heat-resistant alloys are also included in this part.

Part II (1085 pages) contains 74 technical papers, with discussion. These contain the symposium on Aircraft Ma-

(*Continued on next left-hand page*)

BLUE BIRD SMASHES SPEED RECORD!

MALCOLM CAMPBELL DRIVING NAPIER-POWERED CAR WITH NICKEL STEEL PARTS, MAKES 245 M. P. H.

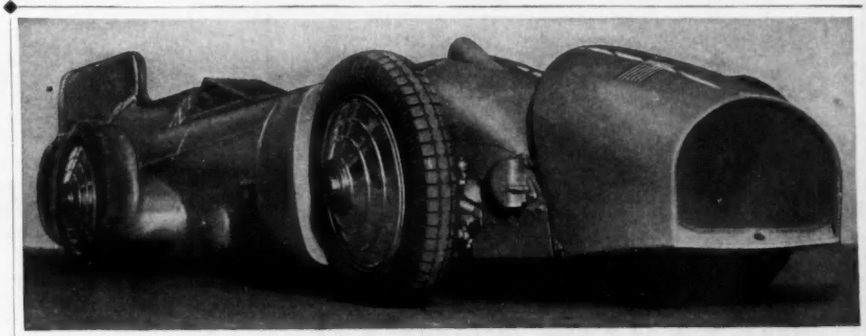
Nickel Alloy Steels chosen to withstand terrific shocks encountered at breath-taking speeds.

ANOTHER world's speed record broken! Another triumph for Nickel Alloy Steel!

Sir Malcolm Campbell, daring British holder of many speed trophies, drove his famous Napier-powered Blue Bird II 245 miles per hour at Daytona Beach. In spite of the terrific shocks — in spite of the incessant stress of lightning speeds — the Blue Bird's Nickel Steel parts performed perfectly.

As in all other record-breaking machines on land, air and water, Nickel Steel parts were the choice of the engineers and designers who built the Blue Bird. Crankshaft, connecting rods, propeller shafts, rear axle shafts, frames, transmission, gears and all other structural parts were Nickel Alloy Steel. Could there be a better demonstration of the strength and dependability of Nickel Alloy Steels?

Send for Bulletin No. 7 "Automobile design and Automotive Steels".



Front view of 12-cylinder, 1400 H. P. Blue Bird. Designing Engineers: Thomson & Taylor, Ltd., Brooklands, England. All steels used outside of engine, and majority in engine furnished by English Steel Corporation, Ltd., Sheffield, England. Part of steering mechanism by Adamant Engineering Co., Luton, England. Napier "Lion" engine manufactured by D. Napier & Sons, Ltd., London, England.

LOOK ***at this list of Nickel Steel parts in the Blue Bird:***

Nickel-Chrome-Molybdenum Steel
(Oil Hardened)

Crankshaft	Steering Rocker Shaft
Connecting Rods	Steering Arm
Clutch Disc	Levers
Clutch Centre	Front Axle Swivel
Flywheel Hub	Control Levers

Nickel-Chrome-Molybdenum Steel
(Air Hardened)

Rear Axle Shafts — Propeller Shaft

3% Nickel Steel
(Oil Hardened)

Shackles — Studs — Bolts

3% Nickel Steel
(Normalized)

Main and Sub Frames
Tubular Cross Members

3½% Nickel-Chrome Steel
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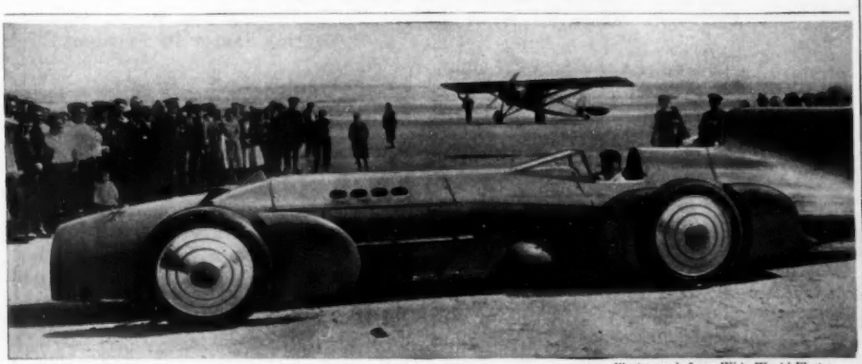

Photograph from Wide World Photos

Sir Malcolm Campbell, British holder of the world's auto speed record, seated in his "Blue Bird II" just before a trial run over the sands at Daytona Beach, Fla.

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Notes and Reviews

Continued

terials, comprised of 17 papers each of which briefly summarizes the present knowledge on some phase of the properties or the testing of aircraft materials, including both structural members and materials entering into aircraft engines.

Rustless Steels as Applied to Automobiles and Aircraft. By W. H. Hatfield. Paper presented before the Institute of Automobile Engineers, London, England, February, 1931. [G-1]

The author is an authority on rustless steel; in fact, he owned in 1925 the first automobile, either in Europe or America, to be fitted with austenitic rustless-steel fittings.

Twenty years ago rustless steels were not in existence; today, as a result of research coupled with painstaking technological development in the steel works, truly resistant steels possessing a wide range of mechanical and physical properties are available.

Applied to automobiles and airplanes, these steels form two classes: one for use where bright surfaces are wanted and the other where structural strength can be maintained at the same time as resistance to corrosive conditions. The austenitic steels employed for automobile bright parts are usually used in their softest condition to facilitate fabrication by cold-working. Concerning the many methods for producing radiator shells, the author feels that pressing is the most satisfactory. If made from austenitic steel they take a beautiful polish.

Elastic and Inelastic Behavior in Spring Materials. By M. F. Sayre. Paper presented at the annual meeting of the American Society of Mechanical Engineers, Dec. 1 to 5, 1930, New York City. [G-1]

A new method of work by which a greatly increased order of accuracy has been obtained in studies of behavior of spring materials in tension has been adopted. It is now possible to give, for several materials, numerical values for the ratė of change of Young's modulus of elasticity with stress.

Tests have confirmed the general principle of a decrease in modulus of elasticity in tension as a result of previous over-strain in tension. The amount of this decrease in modulus with over-stressing is evidently different for different materials and depends upon the previous history of the material. Therefore, to give numerical values, except in general terms, is difficult.

Other papers presented at the annual meeting of the American Society of Mechanical Engineers that may be of interest to the automotive engineer are:

A Survey of Surface-Quality Standards and Tolerance Costs Based on 1929-1930 Precision-Grinding Practice, by R. E. W. Harrison; Radiant-Heat Transmission between Surfaces Separated by Non-Absorbing Media, by H. C. Hottel; Opportunities for Aviation Training, by Joseph S. Marriott; Transmission of Torque by Means of Press and Shrink Fits, by J. W. Baugher, Jr.; Haynes Stellite Cutting-Tools, by W. A. Becker, E. E. Gordon and W. A. Wissler; Engineering Revision an Essential Factor in Accident Prevention, by Lucian W. Chaney.

Plasticity of Copper-Zinc Alloys at Elevated Temperatures. By Alan Morris. [G-1]

Die Pressing of Brass and Copper Alloys. By John R. Freeman, Jr. [G-1]

Studies upon the Widmanstatten Structure, II—The Copper-Zinc Alloys and the Copper-Aluminum Alloys. By Robert F. Mehl and O. T. Marzke. [G-1]

Constitution of High-Purity Aluminum-Titanium Alloys. By William L. Kink, Kent R. Van Horn and P. M. Budge. [G-1]

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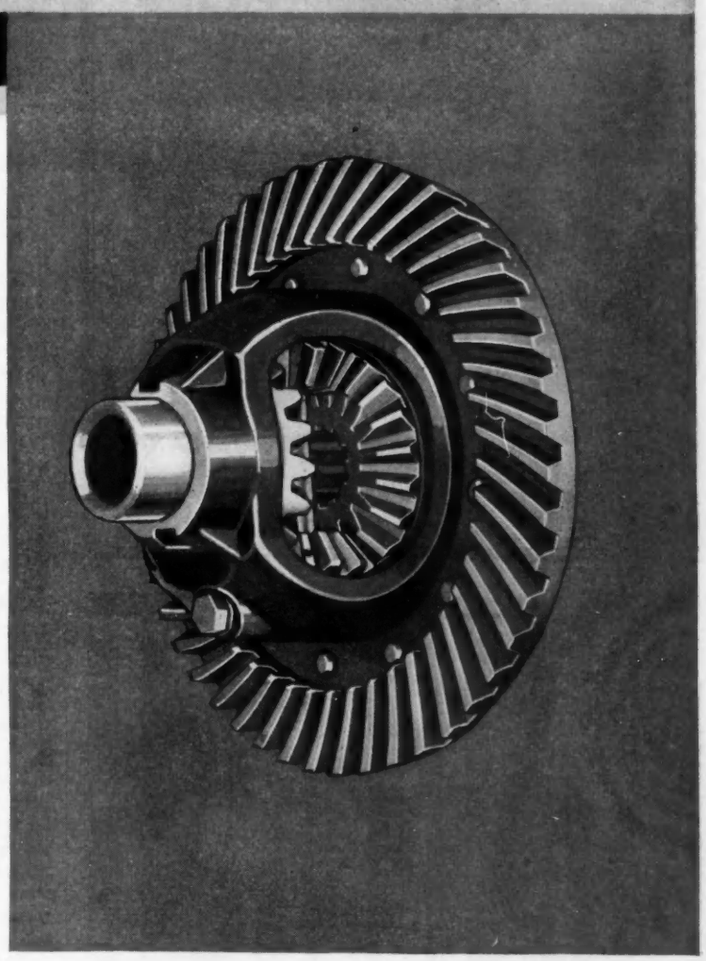

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Notes and Reviews

Continued

Effect of Combinations of Strain and Heat-Treatment on Properties of Some Age-Hardening Copper Alloys. By W. C. Ellis and Earle E. Schumacher. [G-1]

A Thermodynamic Study of the Equilibria of the Systems Antimony-Bismuth and Antimony-Lead. By Yap Chu-Phay. [G-1]

The foregoing six papers were presented at the meeting of the American Institute of Mining and Metallurgical Engineers, New York City, February, 1931.

The Work Factor of Lubricating Oil. By James G. O'Neill. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [G-1]

The usefulness of the standard laboratory tests in judging the quality of lubricating oils has been limited in the past because of the widely different crudes from which lubricating oils are produced and to the varied processes used in their refining. The new method proposed for evaluating lubricating oils seeks to extend the application of the standard laboratory tests so that their results will indicate the service to be obtained from the oils in actual operation. Increases in viscosity, neutralization number, precipitation number and per cent of carbon residue of a lubricating oil, when subjected to an endurance test that stimulates service conditions as found in a forced-feed lubrication system, are expressed numerically by means of formulas, and the average of these results is called the work factor of the oil.

A description of the method and apparatus of the endurance test is given, and the concordance of results obtained is shown when different machines are used to test the same oil. The work factors of turbine, Diesel-engine and aviation oils are discussed with relation to their performance in actual service. The Navy method for purchase of lubricating oils employing the work factor is discussed, as also are the advantages derived from the use of the work factor.

Structural Aluminum Handbook. Published by the Aluminum Co. of America, Pittsburgh, 1930; 119 pp. Price, $1.00. [G-3]

This first edition of the Structural Aluminum Handbook is divided into two parts. Part I deals with the manufacture and mechanical properties of aluminum-alloy structures, structural use and construction practice for aluminum alloys, and the finishing of aluminum surfaces for protection or decoration. Part II gives structural shapes, technical data on miscellaneous structural products, conversion tables and other useful data.

The various aluminum structural shapes correspond generally to accepted steel standards. The elements for sections differ slightly from corresponding values given for steel shapes in some cases, because fillets and roundings have been included in the computations for the aluminum shapes.

Costly Rust of Metal Supply Can Be Prevented if Temperature Is Kept Above Dew-Point in Storage Room. By Joseph Geschelin. Published in *Automotive Industries*, Feb. 21, 1931, p. 256. [G-5]

As a result of an analysis of local humidity conditions in relation to corrosion, the author reveals that, although relative humidity is usually taken as an index of surface corrosion, the real danger indicator is found to be the dew-point temperature, which is critical during the winter months, for, as the temperature of the surroundings approaches the dew-point, precipitation of water vapor occurs. This applies not only to surface corrosion of metal but also concerns the drying of paint and enamel as well as the rusting of parts in the process of machining.

(*Continued on second left-hand page*)

Progressive Planning for Lower Body Costs

WHAT are you doing to lower your present costs of body woodwork?

What can be done to obtain for your company the full benefits of any new economies which *future* conditions in the woodworking industry may produce?

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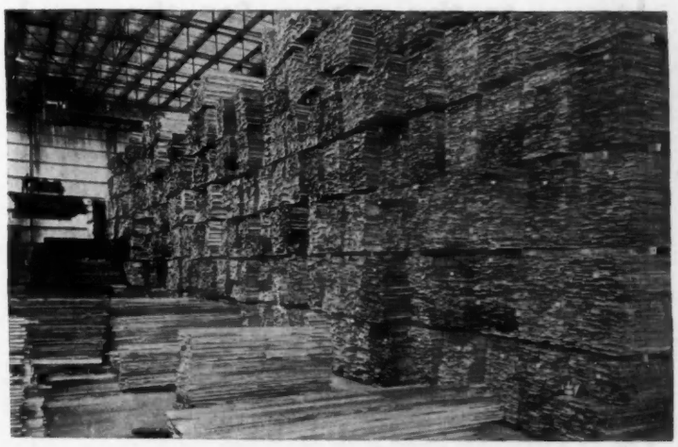

Dry lumber storage in one of the Mengel plants. This building has a capacity of over 4 million feet of lumber. Note crane moving lumber at rear.

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Notes and Reviews

Continued

The logical conclusion inferred from a scientific study of the problem is that atmospheric corrosion of iron and steel stock, such as large sheets, strip and bar stock, can be prevented simply by maintaining the surface temperature somewhat above the prevailing dew-point temperature. This can best be accomplished by isolating such stock within a suitable enclosure provided with the necessary heating arrangement, preferably a unit-heater installation. The size and location of the heater should be carefully worked out, the author warns, to assure a definite control of temperature at the surface of the pile of metal and further to assure a free circulation of air around it.

MISCELLANEOUS

The National Physical Laboratory Collected Researches, Vol. XXII. Published by His Majesty's Stationery Office, London, England, 1930. **[H-1]**

The investigations reported herein were carried out for the purpose of ascertaining whether the assumptions usually made with reference to electrical equipment for radio reception were a sufficiently close approximation to the conditions that obtain in practice. The general conditions for obtaining good sharpness and directivity in a beam system were considered. A method is outlined whereby small radio-frequency voltage can be produced. It was found that the current-carrying capacity of bare copper and aluminum conductors is limited by the heating effects produced by the current. A study is included in the effective resistance of radio conductors and a method of measuring their losses at radio frequency; also an investigation concerning the efficiency of end connection.

The highly technical character of these papers makes them difficult reading for the layman.

A Handbook of English in Engineering Usage. By A. C. Howell. Published by John Wiley & Sons, Inc., New York City, 1930, 308 pp. **[H-1]**

This book was written to serve as a guide for the engineer who wants to make his English clear, accurate and concise. It has been arranged with a view to clarity, accuracy and utility. Although designed as a handbook, it may also be used as a textbook in college courses in engineering English.

L'Evolution de la Voiture Automobile pendant les Cinquante Dernières Années. By G. Delanghe. Published in *Le Génie Civil*, November, 1930, p. 227. **[H-1]**

In view of the great and rapid development of the automobile during the last 50 years, will not a point soon be reached beyond which the rhythm of progress cannot be maintained? After summing up a half century of automotive history, the author gives this question a decidedly negative answer. A crisis does admittedly now confront most countries, but this crisis has its origin in profound causes not specifically applicable to the automotive industry. The world still needs more automobiles, as witness the low per capita count in the continents of Europe, Africa and Asia.

Technically, too, the automobile must not be considered at a standstill. The present crisis past, the forward advance will be resumed with increasingly greater force. The future may be faced with confidence. The automobile will be called upon to play an increasingly more important rôle in the economic life of the world and to continue to inspire progress in the industries contributing to its production. Like the airplane, it is an index of our epoch and will, as the years go on, place upon general conditions of life a deeper and deeper imprint.

This prophecy concludes a brief but inspiring history of automotive development, classified in four periods: that of the origin of the idea, the years from 1875 to 1900, the twentieth century through the war and the present time.

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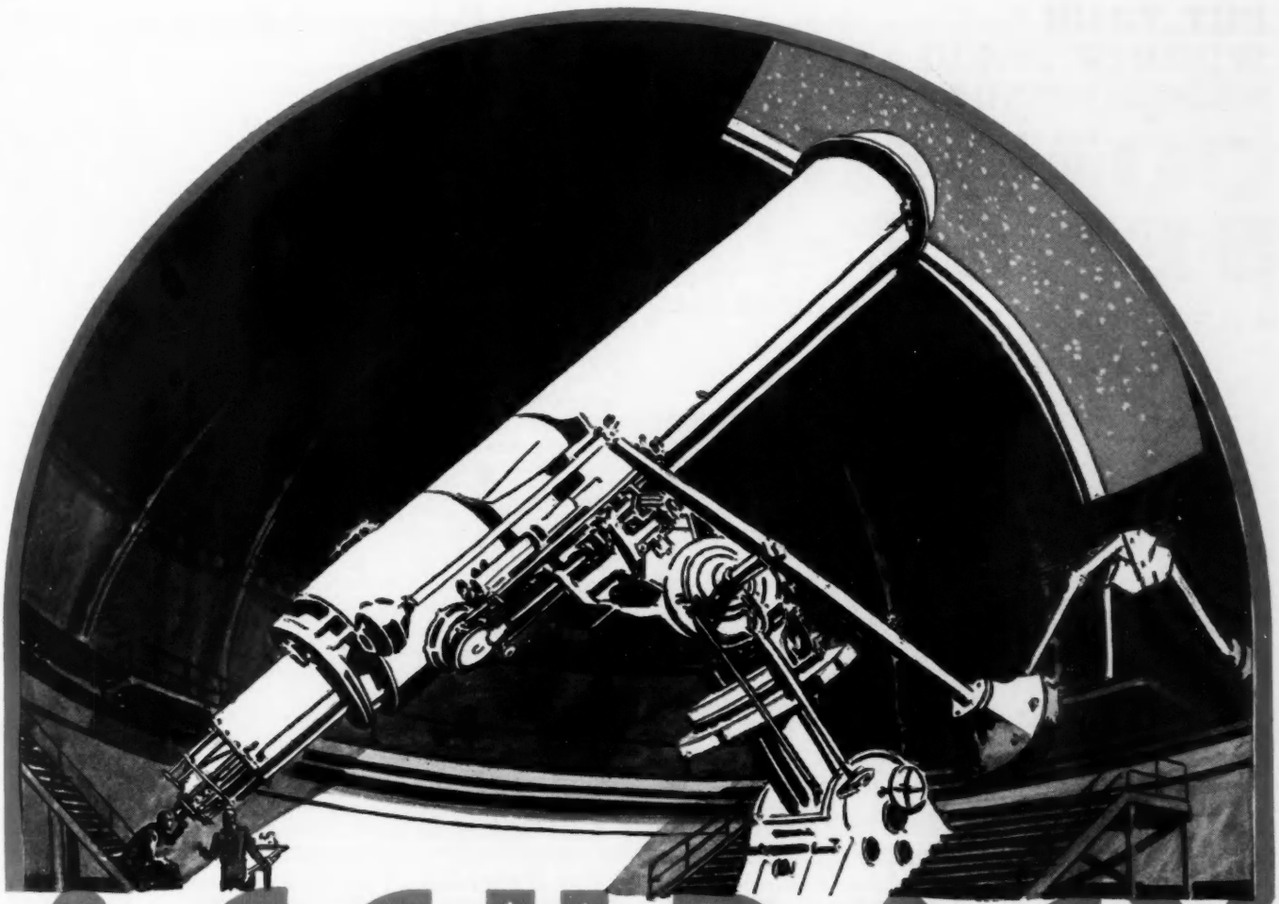

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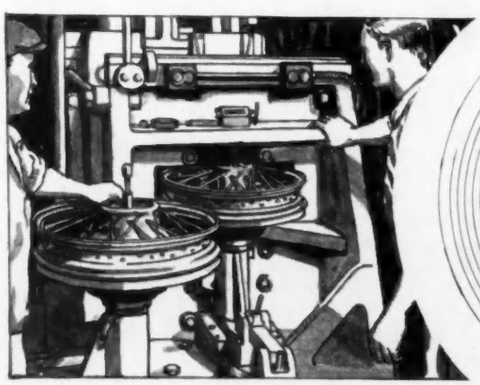

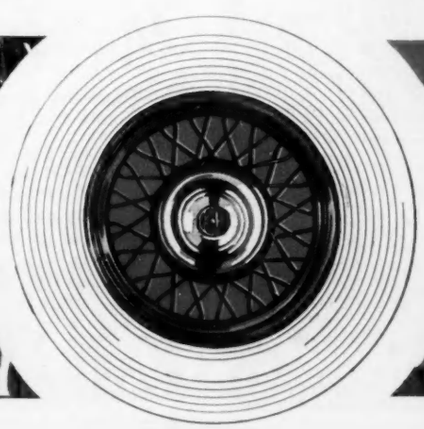

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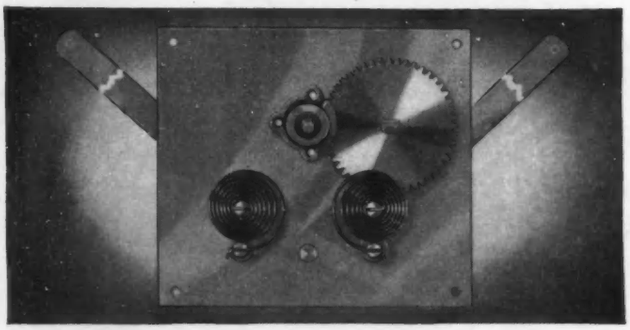

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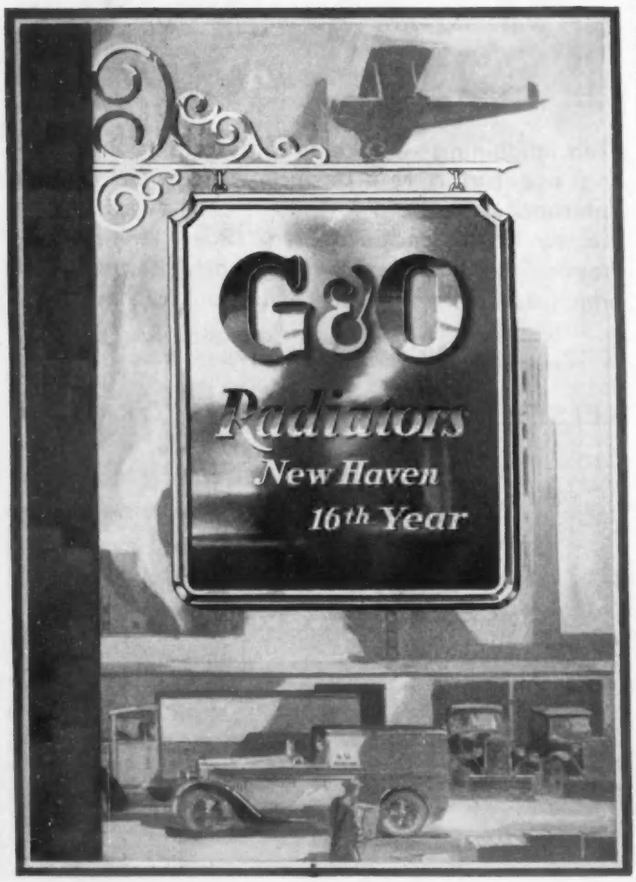

Notes and Reviews

Continued

The Response of Japanese Waltzing Mice and Canaries to Carbon Monoxide and to Atmospheres Deficient in Oxygen. By W. P. Yant, F. A. Patty, H. H. Schrenk and L. B. Berger. Published by the Department of Commerce, Bureau of Mines, October, 1930; 12 pp. **[H-1]**

The investigators found that both canaries of average susceptibility and waltzing mice will give indications of carbon monoxide in advance of marked discomfort and serious harm to man when concentrations are within a 0.14 to 0.16-per cent range and when the activity of man does not exceed the equivalent of walking. Waltzing mice exposed to this range gave positive indications of carbon monoxide after 5 to 10-min. exposure, whereas the canaries generally failed to give indication after 75 to 131 min. Canaries are thus unsatisfactory for giving warning in this lower range of concentrations, because man could acquire a very discomforting and perhaps harmful degree of poisoning before observable symptoms occurred in the birds.

Although waltzing mice appear to be slightly more sensitive to atmospheres deficient in oxygen than canaries and the latter slightly more sensitive than man, the margin of time between serious response of man and observable response of these animals is not wide enough for either canaries or waltzing mice to be of practical use for avoiding harmful exposure of man.

Whither Mankind. Edited by Charles A. Beard. Published by Longmans, Green & Co., New York City, 1930; 408 pp.

Toward Civilization. Edited by Charles A. Beard. Published by Longmans, Green & Co., New York City, 1930; 307 pp. **[H-3]**

Both of the foregoing two books present views of modern civilization but from entirely different angles. The authors of the first book view the present in the light of history, whereas the authors of the latter view the future from the material now on hand. The contributors in the first instance are scholars of the humanities—ethics, economics and law; those of the second are men of scientific training and practical occupation.

These 34 critical estimates of modern civilization contain many contradictions and varied conclusions as to the future of humanity, but on the whole the papers are unbiased, well written and worthy of consideration.

Five Years of Research in Industry, 1926-1930. Compiled by Clarence J. West. Published by the National Research Council, New York City, 91 pp. Price, 50 cents. **[H-3]**

This booklet is a compilation of papers dealing with the value of industrial and scientific research, especially as they relate to a given industry, and papers discussing the future of and the problems facing industry today.

The bibliography for Aeronautics, Automotive Engineering, Gas and Oil Engines, Iron and Steel, Lubrication, Machine-Tools, Metallurgy, Non-Ferrous Metals, Paint and Varnishes, Petroleum, Rubber, Transportation, and Welding should be valuable to the automotive engineer.

This Scientific Age. By D. C. Jackson and W. P. Jones. Published by John Wiley & Sons, Inc., New York City, 1930, 353 pp. Price, $2. **[H-3]**

These essays on modern thought and achievement are written by authors of recognized scientific and literary ability. They are devoted to a modern treatment of science, give glimpses of both the past and the future, and touch on virtually everything concerning the age of science. The non-technical aspects of this age of science and its developments are presented in this well-chosen selection of readings.

At the beginning of each essay there is a biographical sketch which adds to the interest of the book.

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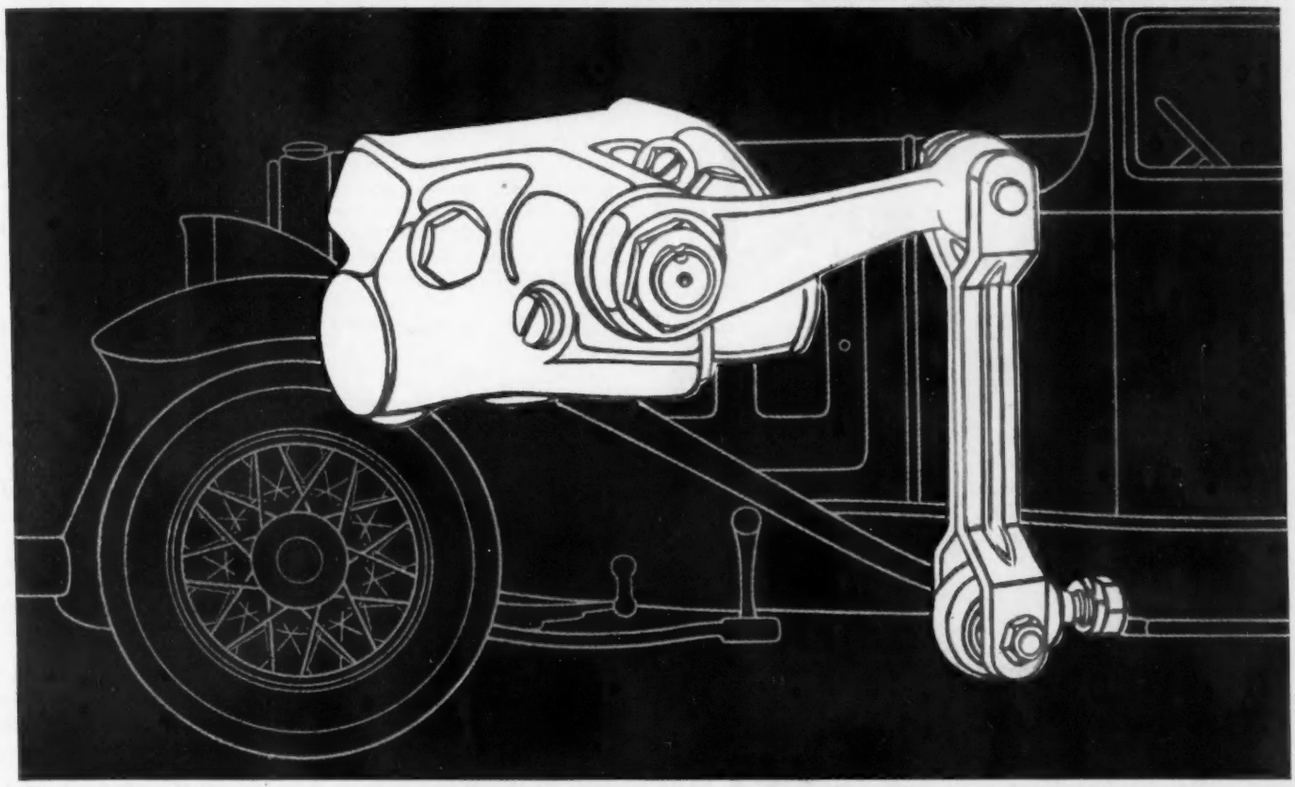

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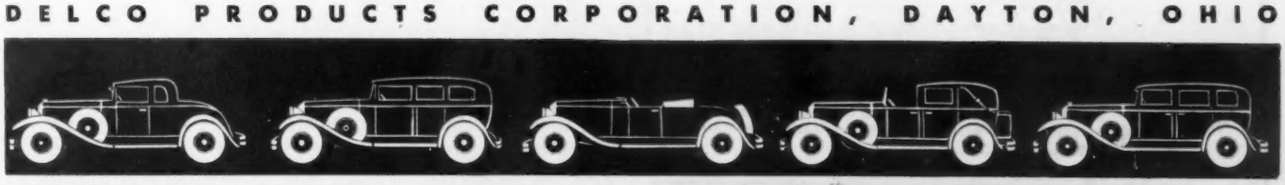

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Notes and Reviews

Continued

Branham Automobile Reference Book. Published by Ben P. Branham Co., Chicago, 1930, 512 pp. Price, paper binding, $1; deluxe binding, $2. **[H-3]**

This is a volume of official and reliable information concerning automobiles. The location of the serial and engine numbers of virtually all passenger and commercial vehicles from 1923 to 1930 are given; also the style of body and weight of each type, the serial numbers with the actual N.A.C.C. and S.A.E. horespower rating and bore and stroke in inches and the factory list price of each car.

Accident Prevention. By J. A. A. Pickard. Published in *The Journal of the Institute of Transport*, December, 1930, p. 73. **[H-3]**

After giving a review of the various classifications of accidents, the author concentrates his attention upon street accidents. The statistics show that about one-half of the victims of street accidents are pedestrians. Errors of judgment on the part of pedestrians when crossing the road are the cause of a very large proportion of these accidents.

The author points out the desirability of road widening and improving of visibility at corners and road junctions. While white lines properly located have a psychological effect upon drivers and automatic signals give a very definite and unmistakable signal, some device should be invented that would come within the driving vision.

Local safety work in the form of instruction among children, newspaper cooperation, posters or films, investigation of accidents and an annual Safety Week have done much to prevent accidents.

Economic Control of Engineering and Manufacture. By Frank L. Eidmann. Published by the McGraw-Hill Book Co., Inc., New York City and London, 1931. Price, $4.00. **[H-5]**

In this book the author points out some of the problems of engineering and manufacturing, the solution of which depends upon economic analysis, and presents methods of approach for the industrial engineer. Many of the examples are drawn from actual practice. Although no fixed general formulas can be given, the principles presented may be applied.

The material has been gathered from many sources and over a period of years. It covers modern management, selection and purchase of materials and equipment, economic considerations in selection and purchases, planning for production, making versus buying power, wage plans, and many others. The subject matter has been used by the author as the basis of a course in the School of Engineering at Princeton University.

Professor Eidmann is a member of the American Society of Mechanical Engineers and the S.A.E.

The Application of Spectroscopic Apparatus to Industry. By Charles C. Nitchie. Paper presented at the annual meeting of the American Society of Mechnical Engineers, New York City, Dec. 1 to 5, 1930. **[H-5]**

In this paper a general description of the principles, instruments and methods of use of spectroscopy is followed by a brief discussion of some ways in which such methods are employed in the industrial field.

Materials-Handling Methods in the Fisk Tire Plant. By C. E. Maynard. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. **[H-5]**

The part that handling-equipment has played in a program of cost reduction and quality improvement in the Fisk Tire Co. plant is discussed. The cost of improvements has to be justified by a reduction in operating cost or an improvement in quality. There are no limitations on the

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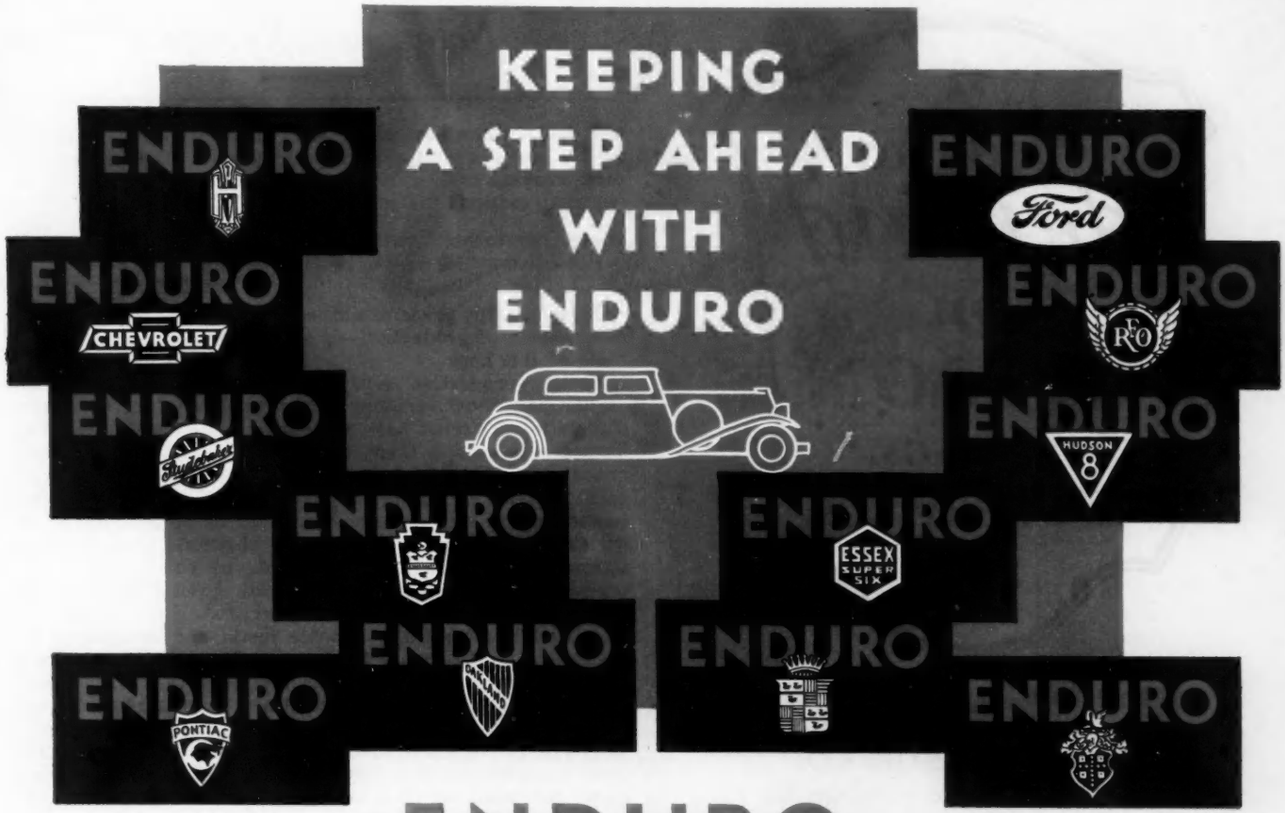

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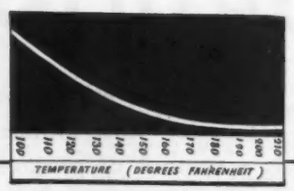

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Notes and Reviews

Continued

cost of materials-handling equipment provided a saving can be made within a reasonable period. Comparing factory trucking costs of 1925 with those of the present, a 50-per cent reduction is noted.

Hochbeanspruchte Automobilteile. By Alfred Tücking. Published by M. Krayn, Berlin, Germany; 141 pp.; 89 figs. [H-5]

An important phase of automotive engineering—the technical aspect of production—is selected by the author as the topic of this book.

Design, production methods and material selection, the author points out, are not strictly isolated functions; specialists in each must have some knowledge of the other two branches to enable them to make the most effective contribution to the finished vehicle. The designer gives to each part the form which has been shown by theoretical considerations and experimental test to be best suited to withstand mechanical, dynamic, thermal and chemical stresses and to meet the demands of economical series production. The selector of material, having in mind the strength requirements of the part and the efficient use of material, chooses the suitable metal and designates the mechanical and thermal treatment. Finally, the processes that will shape the part to the desired form and conserve the desirable properties of the material are determined upon.

The author's purpose is to set forth briefly and in simple language the common knowledge that must be had in the three departments of design, production and material selection. He takes up in a separate chapter each of the important parts of an automotive vehicle and describes the stresses to be met, the important design factors, and recommends suitable material and production methods.

MOTORCOACH

Passenger-Carrying Vehicles. By George J. Shave. Published in the *Journal of the Institute of Transport.* January, 1931, p. 119. [J-3]

Six types of motorcoach are described and the various territories in which each can be used to advantage are discussed. The evolution of the bus in the history of the London General Omnibus Co. makes interesting reading.

For the bus or coach of the future, the author suggests the following: a chassis having a center of gravity as low as possible, with final reduction of the worm type; compression-ignition engine giving idling speed at approximately 300 r.p.m., With a maximum speed up to 2500 r.p.m.; engine to develop not less than 100 hp. at 2000 r.p.m.; to be fitted with some form of infinitely variable gear or, perhaps, an electric transmission, as the compression-ignition engine in its present state can be used more satisfactorily with electric transmission; four-wheel brakes of the assisted type; the driver to be placed in forward position by the side of the engine; body to be constructed entirely of metal, with double deck and to be of the top-cover type; seating and other comforts for the passengers should be given special attention.

Electric Railways Operating Motor Buses. Published by the American Electric Railway Association, New York City, in 1930, 105 pp. [J-4]

A list of 385 electric railway companies operating motor coaches shows the number of such vehicles operated by each, the class and type of service, route mileage, type, make and capacity of coaches and the dates service started. It shows also trolley bus operations.

MOTOR-TRUCK

Motor-Trucks on New York Farms. By C. W. Gilbert. Bulletin 507. Published by the Cornell University Agricultural Experiment Station, Ithaca, N. Y., 1930; 55 pp. [K-2]

After relating the findings of the survey conducted to

(*Continued on next left-hand page*)

rinkles

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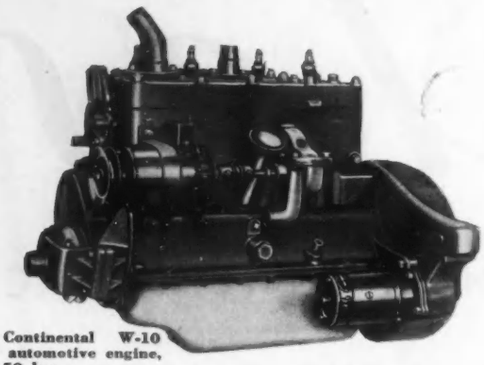

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Notes and Reviews
Continued

ascertain the cost of operating motor-trucks on New York State farms, the author discusses the advisability of purchasing a truck under the following headings: The present and probable future amount of hauling to be done; the possibilities of hiring other truck owners to do this hauling at a lower cost; the amount and value of man and horse labor that could be saved by using a truck; the relative costs of hauling with trucks and with horses; the present condition of the roads over which the hauling would be done, probable improvement of these roads, or the possibility of securing new roads; the possibilities of obtaining a wider choice of markets with prices which will justify the extra cost of hauling to such markets; and the possibility of using the money to better advantage for any other part of farm business.

With the increasing use of motor-trucks on farms and the continuing scarcity of farm labor plus the relatively high wages demanded, there are favorable signs that more farmers will use trucks.

Commercial Motor-Vehicles. By C. le M. Gosselin. Published in the *Journal of the Institution of Transport*, January, 1931, p. 116. [K-3]

The goods-carrying vehicle is the subject discussed by the author. First, he takes up the manufacturer's side of the question, then gives what he believes to be the essential requirements of the user: namely simplicity, reliability, durability, and economy of operation. The latest motor-truck models have many complications, and the author wonders, if the development continues, how far such vehicles can really be serviceable except in the hands of an expert staff. He advocates the standardization of parts, especially between different models of the same make.

In regard to the body work of commercial goods vehicles in general, including cabs, platforms and special bodies of the various types, he feels that the manufacturer is too frequently ignorant of the troubles of the user, and not infrequently is content to remain so, provided that his sales are maintained.

Automotive Route Studies. By Eugene Power. Published in the Proceedings of the 11th Annual Meeting of the American Petroleum Institute, Section 11, p. 48. December, 1930. [K-4]

Herein are described briefly the service problems of the petroleum industry. The author classes automotive route study under the headings of delivery within city limits or a congested area, and deliveries to be handled in country area or small town. The various types of equipment supplied for a given territory are considered. In the case of city deliveries, traffic restrictions have to be carefully analyzed and studied first to determine the type of equipment to be used.

A more detailed analysis is necessary for the country or less congested areas. Such things as roads, mileage and gallonage have to be considered. It is necessary to consider each field carefully in order to select the most useful type and size of truck to cover it, so as to serve all types of deliveries—bulk, package, or both.

At this same meeting of the Institute J. F. Winchester, in his report of the Committee on Automotive Transportation, gave an account of the progress made during the year and of the cooperative work with the S.A.E. and other organizations upon the problem of automotive-vehicle design.

Another paper, Economics of Automotive Transportation, by A. F. Coleman, gives a review of the use of motor-trucks in the transportation of petroleum products. This paper should be of help to executives who face problems such as expediting deliveries, reducing plant maintenance, establishing ferry service and selecting suitable equipment.

(*Concluded on next left-hand page*)

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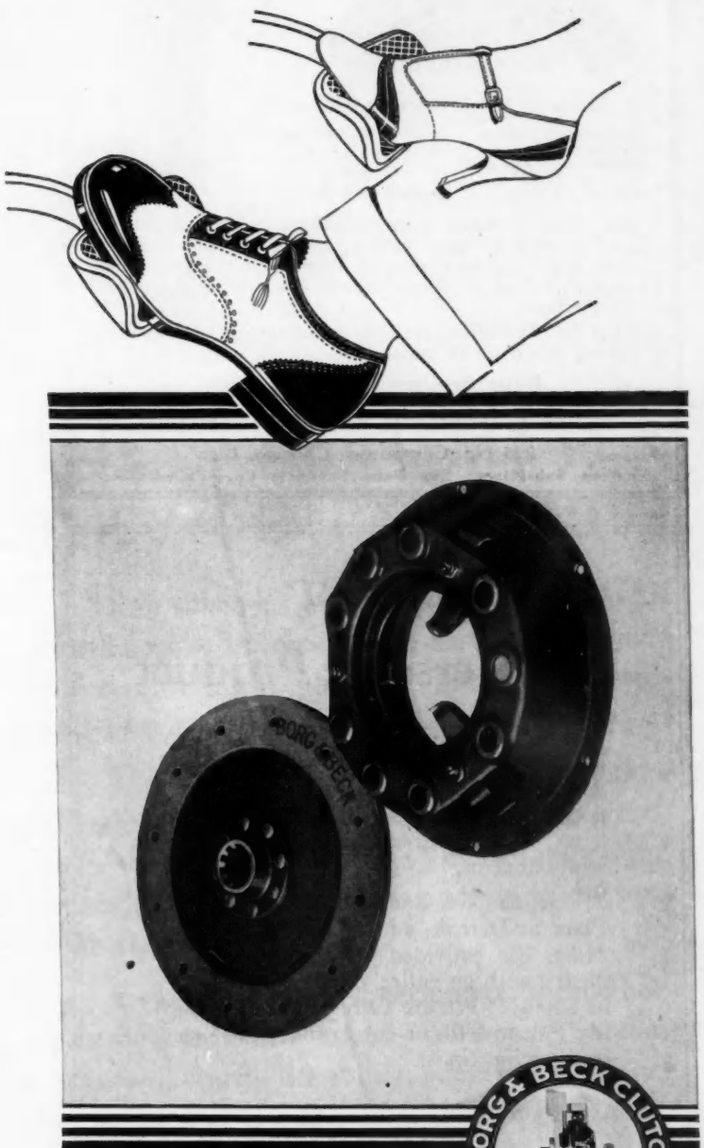
THE light, smooth action of a Borg & Beck clutch is proverbial among automotive engineers. That is one reason why so many women drivers can handle heavy cars with ease—the labor of gear shifting has been removed by Borg & Beck's characteristic easy action.

About 70% of today's cars are bought because they are pleasing to a woman. The first thing she notices is the action of the clutch; if it's a Borg & Beck, the job of pleasing her is made easy.



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Notes and Reviews

Concluded

PASSENGER CAR

Attainment of Uniform Color Standards Approaches with Introduction of Spectrophotometers. By Joseph Geschelin. Published in *Automotive Industries*, Dec. 6, 1930, p. 825. [L-5]

Fitting Photo-Electric Tubes into the Scheme of Automotive Production. By Joseph Geschelin. Published in *Automotive Industries*, Jan. 10, 1931, p. 64. [L-5]

In these two articles Mr. Geschelin discusses some of the industrial and technical applications of the photo-electric tube, commonly called photo-electric cell.

The development of the automatic spectrophotometer or color analyzer seems to be a definite approach to a solution of the problem of specifying and controlling color in automobile finishes.

Briefly, this machine is designed for automatically producing a spectral-distribution curve of any color sample, thus providing a graphic method of scientifically measuring color, of resolving any color into a definite and unmistakable specification which may take the place of color samples or word pictures. The resulting record can be set up as a permanent, unchangeable standard which can be duplicated and matched.

The second article covers briefly other applications of the photo-electric tube which may be classified roughly as: (*a*) indicating and recording; (*b*) sorting, grading and matching; and (*c*) automatic control, relaying and so forth. Specific examples cited are the counting if items where high speed is required and where products possessing high temperatures might wear out the mechanical counter; the automatic starting and reversing of any type of machine-tool; opening doors; as temperature indicators, and so forth. Another use is as a safety device on machinery where the workmen may come into contact with the moving part, as on a press. The article concludes with a list of references.

Automobile Plant Depreciation and Replacement Problems. By F. G. Woollard. Paper presented before the Institute of Automobile Engineers, London, England, Jan. 6, 1931; 15 pp. [L-5]

The author of this paper recommends that those in charge of a factory should consider the depreciation charge as a factor in manufacturing costs. Along with the plant record, a maintenance log should be kept. In the case of the automobile, every car and every spare part should pay toll to cover its obligation to the machines and the other plant and buildings which made its production possible. Probably the amount of labor employed on machining the units will be found the best basis for determining the incidence of the depreciation charge. The fund thus accumulated should be actively employed in the replacement of plant by more accurate, more suitable and more highly productive units.

Die Verwendung von Stahlrohr im Automobilbau. By W. Reinecke. Published in *Automobiltechnische Zeitschrift*, Dec. 31, 1930, p. 865; Jan. 10, 1931, p. 11. [L-5]

The increasing popularity of steel tubing for automobile construction has been due, the author points out, to its large strength-weight ratio, and he compares the solid with the hollow shaft in this respect. The two types of tubing—seamless and welded—are also compared, and conclusions are drawn in favor of the latter on the ground of its cheapness and the ability to manufacture it to closer limits of tolerance. The increasing reliability of welds due to improvements in the process is also commented upon.

The different forms in which steel tubing can be obtained are illustrated, and its use for the following parts suggested: crankshafts, intermediate shafts, connecting-rods, axles, steering-gear connecting-rods, brake shafts and frame members. Three types of use are treated in detail and examples given; these are crankshafts, front axles and frame members.

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You seldom hear a car owner mention his North East Speedometer to a service man. Since it keeps on functioning to his complete satisfaction, year after year, what is there to talk about?

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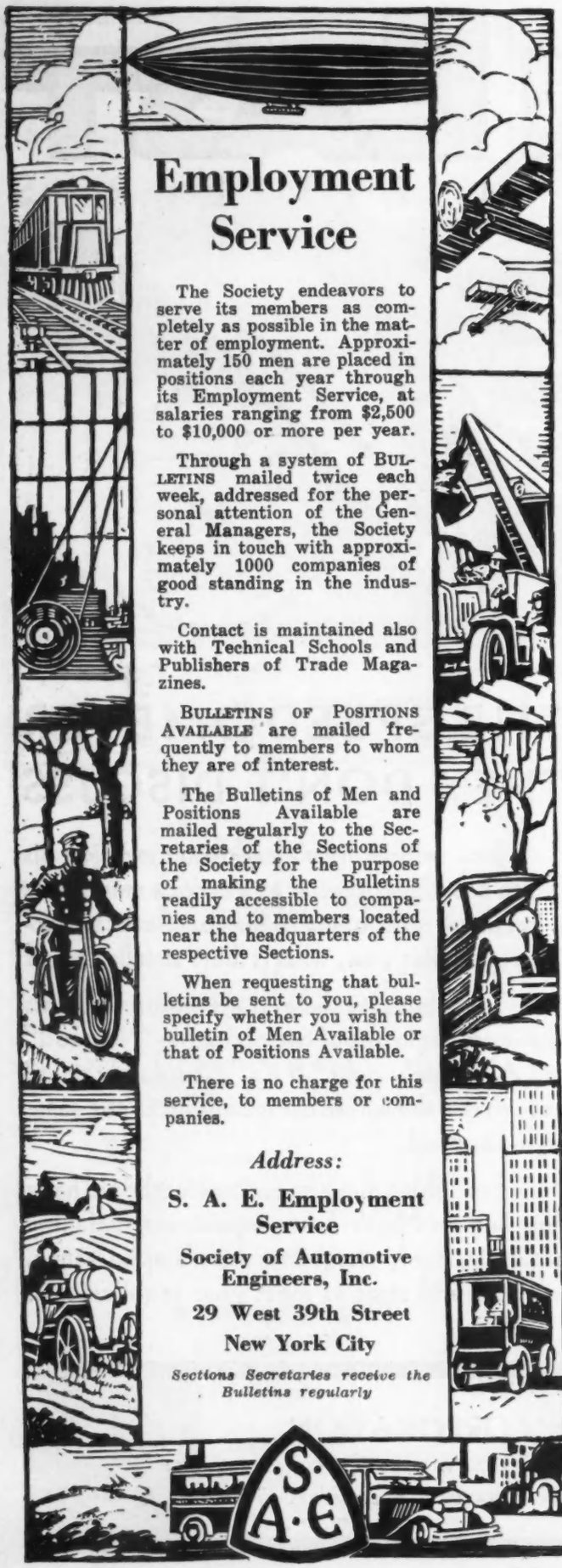

Employment Service

The Society endeavors to serve its members as completely as possible in the matter of employment. Approximately 150 men are placed in positions each year through its Employment Service, at salaries ranging from $2,500 to $10,000 or more per year.

Through a system of BULLETINS mailed twice each week, addressed for the personal attention of the General Managers, the Society keeps in touch with approximately 1000 companies of good standing in the industry.

Contact is maintained also with Technical Schools and Publishers of Trade Magazines.

BULLETINS OF POSITIONS AVAILABLE are mailed frequently to members to whom they are of interest.

The Bulletins of Men and Positions Available are mailed regularly to the Secretaries of the Sections of the Society for the purpose of making the Bulletins readily accessible to companies and to members located near the headquarters of the respective Sections.

When requesting that bulletins be sent to you, please specify whether you wish the bulletin of Men Available or that of Positions Available.

There is no charge for this service, to members or companies.

Address:

S. A. E. Employment Service

Society of Automotive Engineers, Inc.

29 West 39th Street

New York City

Sections Secretaries receive the Bulletins regularly

Personal Notes of the Members

(*Continued from p. 493*)

Corp. of New York City, for the last two years, is now sales manager of the Pierce-Arrow division of the S. P. A. Truck Corp., in Buffalo.

Since being elected to Member grade in the Society in 1926, Mr. Preble has been a very active worker on Society Committees. From 1927, when he was regional service manager in New York City for the White Motor Co., he has served as a member of the Transportation and the Operation and Maintenance Committees and in 1930 he was a member of the Research Committee.

C. W. Brooker, a Foreign Member of the Society, has relinquished his position with General Motors Near East, at Alexandria, Egypt, as service and sales representative for Iraq, and is now inspection engineer and assistant to the manager of Lex Garages, Ltd., of London, England.

Le Roy Chadbourne has been engaged as a traffic representative for the Eastern Air Transport, Inc., of Brooklyn, N. Y. He formerly was employed as a test engineer for the Wright Aeronautical Corp., of Paterson, N. J.

Lee M. Clegg has recently been elected vice-president in charge of sales for Thompson Products, Inc., of Cleveland.

John Coapman was recently appointed sales representative for the Timken-Detroit Axle Co., of Detroit. He previously held similar positions with the Spicer Mfg. Corp., of Toledo, Ohio, and the Brown-Lipe Gear Co., of Syracuse, N. Y.

P. A. Collins, having relinquished his post as sales manager of the Detroit office of the Muncie Products Division of the General Motors Corp., of Muncie, Ind., recently became associated with the Olds Motor Works of Lansing, Mich., in the capacity of experimental engineer.

S. E. Donohue is now associated with the John Deere Wagon Works, of Moline, Ill. His former position was that of engineer with the A. L. Powell Power Co., of Oak Park, Ill.

G. R. Fairchild has recently been appointed assistant to the works manager of the Cruse-Kemper Co., of Ambler, Pa. His previous connection was with the Buick Motor Co., of Flint, Mich., by which he was employed in the salvage department.

Robert H. Fletcher is now a flying cadet in the United States Army Air Corps and is stationed at San Antonio, Texas. He was formerly employed as a mechanic with the New York, Philadelphia & Washington Airways Corp., of the City of Washington.

Having relinquished his post as vice-president and chief engineer of the Issoudun Aircraft & Mfg. Corp., of Northville, Mich., **A. C. Hamilton** is now connected with the Automotive Fan & Bearing Co., of Jackson, Mich., in the capacity of aeronautic engineer.

J. L. Harris, a former salesman for the Mack International Motor Truck Corp., at St. Louis, is now St. Louis branch manager for the Sterling Motor Truck Co.

J. W. Hobbs was recently appointed general manager of the George W. Borg Corp., of Chicago. He previously held the position of sales manager for the Mechanics Universal Joint Co., of Rockford, Ill.

Newton S. Hoerle, a former engineer at the Muskegon, Mich., plant of the Continental Motors Corp., is now an automobile and engine production engineer for the Automobile & Tractor Corp., of the U. S. S. R., at Moscow, Russia.

Ralph Hulton has accepted the position of sales engineer with the Spicer Mfg. Co., of Toledo, Ohio. Prior thereto he was sales manager for the Lovejoy Mfg. Co., of Boston.

M. R. Hutchinson, Jr., recently joined the Packard Motor Car Co., of Detroit, in the capacity of engineer.

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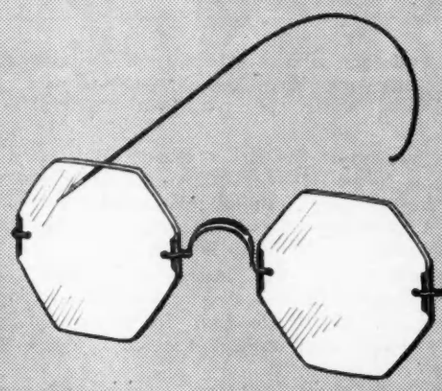

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Did you ever try wearing someone else's spectacles? Awful wasn't it? To correct your vision and protect your eyesight, your eyes must be carefully examined. Then lenses must be skilfully ground to meet the individual characteristics of your eyes.

So it is with governors for internal combustion engines. A governor to give the most efficient and most dependable performance must be scientifically designed to meet your individual requirements.

There are no "standard models" of PIERCE GOVERNORS. Every PIERCE GOVERNOR is scientifically designed to meet the individual requirements of the manufacturer for whom it is built.

PIERCE engineers have solved the governor problem for more than 350 manufacturers. No other governor is so widely used as standard equipment. No other governor approaches PIERCE in sensitivity or dependability.

No matter how wide or sudden the variation PIERCE GOVERNORS respond *instantly*, without power loss and with minimum speed variation.

PIERCE GOVERNORS can be built to be positively sealed (foolproof and tamper-proof) or with quick speed change.

Submit *your* governor problems to PIERCE engineers for study and recommendation.

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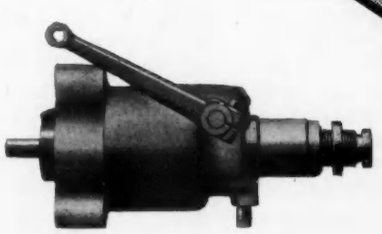

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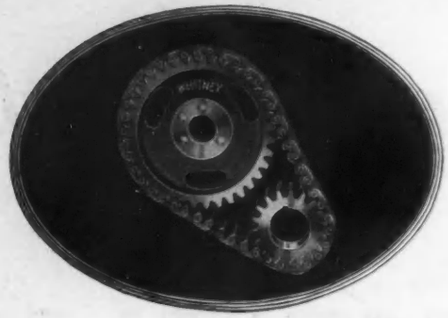

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Personal Notes of the Members

Continued

Kenneth Lydecker is now special representative for the Victaulic Co. of America, of New York City. He formerly represented The White Co., with headquarters at Long Island City, N. Y.

With the merger of the Robert Bosch Magneto Co. and the American Bosch Magneto Corp. to form the United American Bosch Corp., **Rudolf Mangold**, former chief draftsman of the Robert Bosch Magneto Co., was made assistant to the vice-president of the new company.

C. D. McCall recently took charge of the sales and engineering office of the Muncie Products Division of the General Motors Corp., of Muncie, Ind. He previously held the position of manager of Manning, Maxwell & Moore, Inc., of Detroit, Mich.

J. W. Mills has resigned his directorship of the Kelsey-Hayes Wheel Co., Ltd., of London, England, and is now in charge of the experimental engineering department of Humber, Ltd., of Coventry, England.

J. L. Morgan has resigned as experimental engineer with the Auburn Automobile Co., of Auburn, Ind., and has assumed the duties of engineer with the Jamestown Metal Equipment Co., of Jamestown, N. Y.

Charles Nelson, Jr., is now employed as a tool designer by the Ahlberg Bearing Co., of Chicago. He previously held the position of chief draftsman with the Strom Bearing Co., also of Chicago.

Having relinquished his post as designer on cars with the Triumph Motor Co., Ltd., of Coventry, England, **F. G. Parnell** is now associated with the Humber-Hillman-Comer Combine Co., of Coventry, as chief designer in the light-car section.

F. O. Paul has been appointed a special sales representative of the Ex-Cell-O Aircraft & Tool Corp., of Detroit. He formerly represented the Carboloy Co., Inc., as district sales manager of its Dayton office.

Carl D. Peterson has joined the Spicer Mfg. Co., of Toledo, Ohio, as an executive engineer. His former post was with the Brown-Lipe Gear Co., of Syracuse, N. Y., in the capacity of chief engineer.

R. Spotswood Pollard, until recently sales engineer for the Curtiss-Wright Flying Service, of New York City, has accepted a similar post with the Pyle-National Co., of the same city.

C. I. Preston is now a research engineer with the Lawrance Engineering & Research Corp., of New York City. He was formerly chief engineer of the Lambert Aircraft Engine Corp., of Moline, Ill.

J. Otto Scherer has severed his connection with the Junkers Corp. of America, and is now in the independent field as a consulting engineer in Detroit.

Harry A. Schwartz recently accepted the position of general manager of the Montpelier Mfg. Co., of Montpelier, Ohio. Before this change he was employed as research engineer for permanent-mold development with the American Foundry Equipment Co., of New York City.

Clifford William Smith is now serving as a designer for the International Motor Co., of Allentown, Pa. He was formerly a body layout man for the H. H. Franklin Mfg. Co., of Syracuse, N. Y.

Word has been received that **F. M. Starling**, who was general manager of the Gulf State Terminal & Transport Co., Inc., the White Oak Refining Co. and the White Oak Gasoline Co., all of Tulsa, Okla., has recently been elected president of the Penn-O-Tex Oil Co., Inc., of Minneapolis.

J. H. Stirk has taken possession of offices at Vernon House, Nottingham, England, which will serve as his headquarters in connection with his work as chairman of traffic commissioners for the East Midlands Area, a post to which he was recently appointed. His former affiliation in the

(*Concluded on next left-hand page*)

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1,604,122
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The Columbus Bolt Works Co.
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QUALITY :-: SERVICE

Personal Notes of the Members

Concluded

business world was as transport manager of the Birmingham Cooperative Society, Ltd., of Birmingham, England. He was also elected a justice of the peace in that city.

Adam K. Stricker, Jr., formerly sales and service engineer for the Cadillac Motor Car Co., of Detroit, has been transferred to the eastern region of the company's branches and is now employed as a sales engineer on technical education, with headquarters in the General Motors Building, New York City.

William B. Todd has been appointed general manager of sales of the Jones & Laughlin Steel Corp. He was formerly assistant general manager of sales. In 1922, he resigned a vice-presidency in the Union Drawn Steel Co. to join the Jones & Laughlin sales staff as manager of sales of the cold-finished division.

William Ernest Waterhouse, having resigned as general supply manager of Vauxhall Motors, Ltd., of Luton, England, is now assistant export manager of Adam Opel A. G., of Russelsheim on Main, Germany.

R. Masson Webster, Jr., has joined the International Motor Co., of Allentown, Pa., as a draftsman, having resigned from the American Die & Tool Co., of Reading, Pa.

Robert Bruce White has relinquished his position as general sales manager for the Valvoline Oil Co., of New York City, and is now assistant vice-president for the Humble Oil & Refining Co., of Houston, Texas.

Ross E. Willis has assumed his duties as a sales engineer with the Mesta Machine Co., of Pittsburgh, having left the Ready Power Co., of Detroit, of which he was sales manager.

Earl T. Zufall is now employed by the Interstate Public Service Co., of Greenwood, Ind. He previously was a mechanic for Pickwick Stages, Inc., of Los Angeles.

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Occasion

Summer Meeting

Time

June 14 to 19, 1931

Place

White Sulphur Springs, W. Va.

MAKE A NOTE ON YOUR CALENDAR